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Alameda Watershed Management Plan

APPENDIX A
VOLUME III

San Francisco Public Utilities Commission

November 1998

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List of Appendices

The following documents and memoranda were prepared during the course of the watershed management planning process. This information was gathered at specific points in time during the planning process and does not necessarily represent the information contained in the Alameda Watershed Management Plan. Some specific issues noted in the following appendices may have been refined through the planning process. These refinements are reflected in the Alameda Watershed Management Plan.

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A-3 Sunol Valley Resources Management Element, November 1998

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C-5 Technical Memorandum #4: Visual Resources, November 1996

C-6 Technical Memorandum #5: Best Management Practices (to be completed)

C-7 Technical Memorandum #6: Economic Profile of Watershed Land Management by the San Francisco Water Department, November 1993

C-8 Technical Memorandum #7: Demographic Profile of Areas Adjacent to Peninsula and Alameda Watershed Lands, November 1993

C-9 Technical Memorandum #8: General Plans Review, June 1994

C-10 Technical Memorandum #9: Utilities and Infrastructure Review, June 1994

C-11 Technical Memorandum #10: Regional Recreational Facility Inventory, June 1994

C-12 Technical Memorandum #11: SFPUC Policies, September 1993

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- Volume 7, Summer 1997 (to be completed)
- Volume 8, Fall 1997 (to be completed)

D-14 Brochures

- Coordinated Water Management: An Orientation to the Water System of the City and County of San Francisco

[1] *Material in this Appendix has been prepared exclusively for the Alameda Watershed.*

[2] *Material in this Appendix covers both the Peninsula and Alameda Watersheds, and therefore it is a common Appendix to both the Peninsula Watershed Management Plan and the Alameda Watershed Management Plan.*

[3] *The Sunol Valley Resources Management Element Draft Public Involvement Summary Report (August 1995) is included in the Sunol Valley Resources Management Element, Appendix A-3.*

Appendix A-6

Alameda Creek Water Resources Study
Appendices A-1
January 1995

7

ALAMEDA CREEK
WATER RESOURCES STUDY

APPENDICES A-I

PREPARED FOR

SAN FRANCISCO WATER DEPARTMENT

PREPARED BY

BOOKMAN-EDMONSTON
ENGINEERING, INC.

IN ASSOCIATION WITH

BioSystems Analysis, Inc.
Luhdorff & Scalmanini Consulting Engineers
Ogden Environmental and Energy Services Co., Inc.
The Pacific Group

Unpublished Work © January 1995

City & County of San Francisco
Public Utilities Commission

San Francisco Water Department
Water Supply Division
Watershed Management

DATE: February 13, 1995

TO: C.Davis L.Bauer J.Naras M.Mueller

FROM: E.Stewart ES

RE: Alameda Creek Study

Enclosed is the final report by Bookman-Edmonston on the Alameda Creek Watershed fish issues and related Sunol Valley ground water conditions. There are 2 volumes. Volume I is the report; Volume II is the appendices to the report. Both are included.

Bookman-Edmonston will provide a briefing on their report this Friday, February 17, at 1:30 pm. The presentation will be made at the offices of EDAW located at 753 Davis Street, San Francisco.

cc:

A.Moran	vol. I only	
J.Mullane	vol. I only	
R.Brandt	1 copy	
S.Leonard	1 copy	
C.Morioka	1 copy	
B.Camp	2 copies	(1 for FERC)
J.Milstein	2 copies	(1 for DWR)
EDAW - Tina Stott	1 copy	

(415) 872-5900 P. O. Box 730 Millbrae, CA 94030

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B. Technical Advisory Committee Report on Establishment of a Steelhead Fishery in Alameda Creek

C. Alameda Creek Riparian Vegetation Baseline Assessment, Technical Report, May 1993

D. Alameda Creek Revegetation/Restoration Report, February 1993

E. Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan, November 1993

F. Report on Watershed Operations, June 1994

G. Ground-Water and Aggregate Resources, Sunol Valley, June 1994

H. Report on Water Recovery Facilities, June 1994

I. Letter from the State of California Department of Fish and Game Recommending Implementation of Alternative 4 (Protection and Enhancement of Native Rainbow Trout and Non-Game Fishes) as Identified in the Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan, November 1993 (Appendix E)

APPENDIX A

STATE WATER RESOURCES CONTROL BOARD AUGUST 7, 1991 ORDER DISMISSING COMPLAINT OF CALIFORNIA SPORTFISHING PROTECTION ALLIANCE REQUESTING ACTION TO RESTORE AND PROTECT PUBLIC TRUST VALUES IN THE ALAMEDA CREEK WATERSHED

STATE OF CALIFORNIA

STATE WATER RESOURCES CONTROL BOARD

In the Matter of Complaint Requesting Action to Restore Steelhead, Other Fish, Wildlife, and Riparian Habitat in the Alameda Creek Watershed,	ORDER:	WR 91-06
	SOURCE:	Alameda Creek Watershed
	COUNTY:	Alameda and Santa Clara
CALIFORNIA SPORTFISHING PROTECTION ALLIANCE,		
Complainant.		

ORDER DISMISSING COMPLAINT

BY THE BOARD:

1.0 INTRODUCTION

The California Sportfishing Protection Alliance (CSPA) having submitted a complaint against all water users in the Alameda Creek watershed requesting action to restore certain fish, wildlife, and riparian resources; the State Water Resources Control Board (State Board) staff having investigated the allegations raised by the complaint and having advised CSPA that staff intended to take no further action regarding the complaint; CSPA having requested that the complaint be brought before the State Board; the State Board having duly considered the issues raised by the complaint; the State Board finds as follows:

2.0 BACKGROUND

The California Sportfishing Protection Alliance (CSPA) submitted a complaint in January 1991 to the State Water Resources Control Board (State Board) against seven water agencies and all other water users in the Alameda Creek Watershed in Alameda and Santa Clara Counties. The complaint requests that the State Board take action to restore steelhead, other fish, wildlife, and other riparian habitat throughout the 700-mile Alameda Creek watershed.

Prior to the CSPA complaint, California Trout, Inc. (Cal Trout) submitted a complaint requesting that the City of San Francisco be directed to release additional water from Calaveras Reservoir to restore a trout fishery in a three-mile section of Alameda Creek below the dam. In response to the Cal Trout complaint, staff requested comments and recommendations regarding Alameda Creek from the Department of Fish and Game (DFG). DFG staff responded that they had not done any fishery studies on Alameda Creek and did not know of or plan to conduct any fishery studies on the creek. State Board staff also conducted field investigations of Alameda Creek and met with staff from Cal Trout, DFG, and staff from the San Francisco Water Department, which operates Calaveras Reservoir.

Following State Board staff's review of the CSPA complaint, staff advised CSPA by letter dated February 27, 1991 that the statutory adjudication process would be a more appropriate method to address issues of the broad scope and complexity of the issues raised in the complaint. Staff also advised CSPA that there is a lack of technical data relating to fishery resources on Alameda Creek and that State Board staff planned no further action on the complaint.

By letter dated March 12, 1991, CSPA submitted a report regarding establishment of a steelhead fishery in Alameda Creek and stated that the report provided a sufficient basis for acceptance of their complaint. Although the report lists a number of legal, technical, policy and environmental issues, State Board staff advised CSPA by letter dated April 4, 1991 that the report does not provide sufficient technical information to serve as the basis for setting instream flow requirements for fish protection. CSPA responded that they disagreed with staff's conclusion and requested that the subject be brought before the State Board at a workshop.

3.0 ANALYSIS

Resolution of the issues raised in the CSPA complaint would require a detailed examination of the water

resources and use of water throughout the Alameda Creek watershed, as well as extensive research on complex fishery and environmental resources in the watershed. In addition to determining the flow requirements needed for restoration of steelhead trout, a fishery study would also be required to determine if restoration of steelhead trout would be compatible with the trout stocking which DFG currently does in the lower section of Alameda Creek. The State Board has received no indication from DFG that it regards the restoration of steelhead in Alameda Creek as a high priority.

Many of the other issues which would have to be resolved with respect to restoration of a steelhead run in Alameda Creek are identified in the report submitted by CSPA with a letter dated March 12, 1991. As stated in State Board staff's letter of April 4, 1991, however, that report does not provide sufficient technical information to serve as the basis for setting instream flow requirements for fish protection. Consequently, a State Board proceeding to address the issues raised in the complaint would require commitment of substantial resources from the engineering, environmental, and legal staffs. Currently, our limited enforcement resources available for fishery and public trust protection are directed primarily to: (a) watercourses where instream flow requirements

previously have been set; (b) watercourses on which fishery studies have been conducted; or (c) instances involving protection of public trust resources of statewide significance. None of those criteria are met in this instance.

In addition to the necessary technical studies, State Board action to grant the relief requested in the complaint probably would require further documentation and analysis to comply with the California Environmental Quality Act ("CEQA", Public Resources Code Section 21000 et seq.). No source of funding for an environmental impact report or other CEQA documentation has been identified.

Another factor which would compound analysis of public trust protections for Alameda Creek is the fact that the stream is used as part of a ground water recharge/conjunctive use operation in an area which previously experienced a seawater intrusion problem. Thus, any program which would significantly alter the present method of operating the stream may require hydrogeologic studies and hydrology modeling of the various streams, reservoirs, and ground water storage areas in the watershed.

Restoration of steelhead trout in Alameda Creek also would be impeded by several existing physical barriers in the stream including large gravel pits, inflatable flood control dams, and concrete barriers in the stream channel. All of these barriers could serve as obstructions to steelhead migration. To date, no analysis has been done to show the economic feasibility of modifying or removing the physical barriers in the stream channels.

In view of numerous substantial obstacles to measures requested by the complainant, we concur in staff's recommendation that no further State Board resources should be expended in response to the complaint.*

4.0 CONCLUSION

Based on the findings set forth above, the State Board concludes that the CSPA complaint should be dismissed without prejudice to reconsideration of the issues raised in the complaint if significant new information becomes available.

---

* *As indicated in staff's correspondence with CSPA, the statutory adjudication process would provide an alternative procedure for addressing some of the issues raised by the complaint. In particular, a statutory adjudication would provide a means of adjudicating the water rights of all diverters from Alameda Creek and determining their obligations with respect to protection of public trust uses. Before initiating a statutory adjudication, however, the State Board must find that the public interest and necessity would be served by the adjudication. (Water Code Section 2525). Based on the facts discussed above, we believe it is doubtful that the required finding could be made with respect to a petition for a statutory adjudication of Alameda Creek.*

ORDER

IT IS HEREBY ORDERED that:

The complaint of the California Sportfishing Protection Alliance against water users on Alameda Creek is dismissed.

CERTIFICATION

The undersigned, Administrative Assistant to the State Board, does hereby certify that the foregoing is a full, true, and correct copy of an order duly and regularly adopted at a meeting of the State Water Resources Control Board held on August 22, 1991.

AYE: W. Don Maughan
Edwin H. Finster
Eliseo M. Samaniego
John Caffrey

NO: None

ABSENT: None

ABSTAIN: None

Maureen Marché
Administrative Assistant
to the Board

APPENDIX B

TECHNICAL ADVISORY COMMITTEE REPORT ON ESTABLISHMENT OF A STEELHEAD FISHERY IN ALAMEDA CREEK

ESTABLISHMENT OF A STEELHEAD FISHERY

IN

ALAMEDA CREEK

Report of the Technical Committee

May 1989

ON

ESTABLISHMENT OF A STEELHEAD FISHERY IN ALAMEDA CREEK

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- III-C Zone 7 Service Area 1987

References

- Hetch Hetchy (Raker) Act (Sixty-Third Congress, Sess II CH4 December 19, 1913, HR7207)
- Water Rights Permit Nos. 011319 and 011320
- CDF&G "General Fish Screening Criteria, Appendix F"
- Alameda Creek Urban Streams Study (DWR October 1980)
- Alternate Plans for Offstream Storage South of the Delta (DWR May 1984)
- Alameda Creek - Update on Potential for Reestablishing Steelhead Run (K. Burger, EBRPD, October 27, 1983)
- Potential Anadromous Fish Population Size Based on Flow Releases from Different Source Locations in the Alameda Creek Watershed (K. Burger, EBRPD, October 5, 1987)
- Report on Potential Steelhead Population (Charles Hanson, November 13, 1987)

TECHNICAL COMMITTEE REPORT
ON
ESTABLISHMENT OF A STEELHEAD FISHERY IN ALAMEDA CREEK

EXECUTIVE SUMMARY

Steelhead trout are anadromous, meaning that adult fish migrate from the ocean upstream in the winter and reproduce in areas conducive to spawning. Eggs deposited in stream gravels hatch in the spring, with the young fish remaining in the fresh water stream for one or two years until they migrate downstream to the ocean. Steelhead trout require sufficient fresh water flow both to permit the survival of juvenile fish and to permit the migration of spawning fish and the out-migration of the young fish to the ocean as smolts.

Alameda Creek once supported a self-sustaining run of steelhead trout. At the southern end of the steelhead range which extends from Central California to Alaska, Alameda Creek is typical of California coast range streams, with major flows occurring during the rainy season from November through March, and reductions in flow during the summer months.

The steelhead fishery in Alameda Creek declined during the early part of this century as a result of changes in the watershed which reduced flows to the bay (groundwater pumping in the Livermore Valley, Spring Valley Water Co. operations in Sunol and construction of Calaveras Reservoir).

By the late 1950's the Department of Fish and Game considered that a viable steelhead fishery no longer existed in Alameda Creek. Subsequent water supply and flood control projects were then constructed without provision for accommodating anadromous fish (San Antonio Reservoir, Del Valle Reservoir, Corps of Engineers creek channelization project, and ACWD groundwater recharge projects along Alameda Creek).

A Technical Advisory Committee was formed in 1987 to determine if steelhead could be reestablished in Alameda Creek and if so what modifications would have to be made to current conditions and what costs would be associated with these modifications.

The major obstacles to reestablishment of a steelhead fishery are 1) the 10-foot WPRR/BART drop structure in Alameda Creek Flood Control Channel which prevents the upstream migration of steelhead and 2) the lack of sufficient stream flow to the bay during the spring out-migration period.

This report presents four alternatives with respect to establishment of a steelhead fishery.

ALTERNATIVE 1 - NO PROJECT, NO NEW COSTS

This alternative maintains current conditions and does not establish a steelhead fishery. The existing 20,000 to 30,000 planted trout fishery, which is supported by the existing water supply operations in the creek, would be continued.

ALTERNATIVE 2 - MINIMUM STEELHEAD FISHERY; COST RANGE: $225,000 to $1,055,000 (FIRST YEAR)

This alternative involves construction of a fishway at the WPRR drop structure to eliminate the major migration barrier. In addition, because a steelhead fishery is established, ACWD would be required to retrofit its existing diversion facilities (fish screens on all diversion pipes, plunge pools below inflatable dams). No changes or additions to existing water releases would be proposed at this time. The put-and-take trout fishery would be eliminated from Alameda Creek east of Mission Blvd. because the trout compete with steelhead for food. The trout could be relocated to the quarry lake areas or further downstream in the flood control channel west of Mission Blvd.

ALTERNATIVE 3 - MODERATE STEELHEAD FISHERY; COST RANGE: $270,000 to $1,815,000 (FIRST YEAR)

This alternative expands on Alternative 2 by adding a 10 cfs water flow to the bay during springtime smolt out-migration. The report identifies several sources for such a release and the varying potential costs.

ALTERNATIVE 4 - MAXIMUM STEELHEAD FISHERY; COST RANGE: $370,000 to $4,155,000 (FIRST YEAR)

This alternative expands on Alternative 3 by adding flow releases on selected streams to increase available rearing habitat by 23.3 miles. The report identifies potential streams, water sources and their potential costs.

Estimates of the number of fish which could be produced by the project alternatives range from 100 to 2,400 steelhead. A more precise estimate cannot be made without a more detailed assessment of habitat by the instream flow incremental method (IFIM).

Following is a summary of the four alternatives and their respective components, costs, and impacts. More detailed information and back-up material is contained in the body of the report.

TABLE IV SUMMARY OF STEELHEAD ESTABLISHMENT PROJECT ALTERNATIVES

ALTERNATIVES	1 - No Project	2 - Minimum Project	3 - Moderate Project	4 - Maximum Project
	o Current Conditions	o Construct Fishway	o Construct Fishway	o Construct Fishway
			o 10 CFS Flow over Fabridam #2 from March 1 through May 15	o 10 CFS Flow over Fabridam #2 from March 1 through May 15
				o Live stream below Reservoirs
CONDITIONS				
1. Barrier to adult migration	Yes	No	No	No
2. Existing rearing habitat	N/A	16.5 miles estimated	16.5 miles estimated	16.5 miles estimated
3. Additional rearing habitat	None	None	None	23.3 miles estimated
4. Smolt "Out-Migration" assured	No	No	Yes	Yes
5. Fish screens/Plunge Pools required	No	Yes	Yes	Yes
6. Adult migration	N/A	Poor	Self-sustaining	Larger Self-sustaining
7. Put-and-take trout fishery in Alameda Creek east of Mission Blvd.	Yes	No	No	No
8. Steelhead harvest	No	*	*	*
COST ESTIMATES				
First Year Capital	-0-	$225,000 to $1,055,000	$225,000 to $1,055,000	$225,000 to $1,055,000
Annual M & R	-0-	$ 16,000 to $ 91,000	$ 19,000 to $ 93,000	$ 19,000 to $ 93,000
Annual Water	-0-	-0-	$ 45,000 to $ 760,000	$145,000 to $3,100,000

* fishing limited (i.e., none until established, or catch and release; limited harvest once established)

FIRST YEAR CAPITAL COSTS ($)

	LOW	HIGH
Fishways at Barrier	75,000	125,000
Fishscreens at Water Diversions	90,000	870,000
Plunge Pools at Inflatable Dams	60,000	60,000
Subtotal	225,000	1,055,000

ANNUAL MAINTENANCE & REPLACEMENT COSTS ($)

	LOW	HIGH
Fishways at Barrier	8,500	14,200
Fishscreens at Water Diversions	8,200	76,900
Subtotal for Alt. 2	16,700	91,100
Low Flow Channel (4.5 Miles)	2,000	2,000
Subtotal for Alt. 3 & 4	18,700	93,100

ANNUAL WATER COSTS ($)

	LOW (at $30/AF)	HIGH (at $200/AF)
Flow over Downstream Inflatable Dam		
Mar 1 to May 15: 10 cfs x 76 days = 1,500 AF	45,000	
Mar 1 to May 15: 25 cfs x 76 days = 3,800 AF		760,000
Subtotal for Alt. 3	45,000	760,000
Flow for Habitat in Arroyo Del Valle		
May 15 to Oct 30: 5 cfs x 169 days = 1,673 AF	50,190	
May 15 to Oct 30: 20 cfs x 169 days = 6,700 AF		1,340,000
Flow for Habitat in Upper Alameda Creek		
May 15 to Oct 30: 5 cfs x 169 days = 1,673 AF	50,190	
May 15 to Oct 30: 15 cfs x 169 days = 5,000 AF		1,000,000
Subtotal for Alt. 4	145,380	3,100,000

MAY 2 2 1989

OPERATIONAL COMPONENTS OF THE PROPOSED ALAMEDA CREEK STEELHEAD FISHERY

This operational summary is an extension of the Technical Committee Report on the Development of a Steelhead Fishery in Alameda Creek. The Technical Report provides extensive material on the water supply requirements of the proposed fishery, recreational benefits, required capital improvements, as well as a discussion of cost and financial requirements for the proposed fishery.

It might be possible for the involved agencies to implement their portions of the project using periodic coordination and problem-solving meetings similar to the process used to prepare the Technical Committee Report. However, the administrators of the involved public agencies feel that a lead role should be assumed by one of the primary agencies (Alameda County Water District, San Francisco Water District, Alameda County Flood Control District, East Bay Regional Park District, California Department of Fish and Game, U.S. Fish and Wildlife Service) to place overall project responsibility with one agency and to insure that all elements of the project are managed in a timely and efficient manner.

The principal areas of responsibility for the lead agency would include the following:

1. Complete the required studies and technical analysis identified in the Committee Report and prepare the required Environmental Impact Report.

2. Negotiate with the involved water agencies to obtain the necessary water releases for maintaining the fishery.

3. Coordinate the installation of capital improvements required to implement the fishery and assist in obtaining grants, agreements and permits required to implement the project.

4. Coordinate and oversee the operational elements of the proposed steelhead fishery:

    a. Work with the Department of Fish and Game to establish stream restrictions and enforcement of appropriate Fish and Game regulations.

    b. Provide annual maintenance of the fishery structures and coordinate period stream habitat improvements and maintenance of the flow channel within the Alameda Creek flood control reach.

    c. Provide operational and public safety services within sections of the stream open to public fishing.

    d. Coordinate citizen, school, and public information programs about the restored steelhead fishery within Alameda Creek.

Therefore, we seek not only your comments on the project and its components but also whether or not your agency is willing to assume the lead role.

I. INTRODUCTION

The possibility of restoring an anadromous fishery to Alameda Creek has been a topic of sporadic discussion and study for the past 40 years. After inconclusive discussion in the 1950's and 1970's, a task force was formed in 1983 to again examine the question. An inventory of the upper reaches of the Alameda Creek watershed was conducted. The conclusion indicated there could be adequate watershed for anadromous fish. The provision of a sufficient supply of water remains a critical factor in the discussion of this issue. The 1983 task force disbanded without reaching final conclusions.

In August of 1987 elected and appointed officials met to reestablish the study of anadromous fishing in Alameda Creek—the "Alameda Creek Beneficial Use Study." The Technical Advisory Committee has worked on the report since that time.

It was recognized from the beginning of the study that many pieces of information would have to come together in order for there to emerge an understandable description of the elements necessary for an anadromous fishery. The agencies with access to that information and expertise have worked together to frame the issues as clearly as possible. Some of the information is subject to differing interpretations, particularly information related to water availability.

The "Commentary" section provides an opportunity for a more argumentative approach to the issues. It is hoped these perspectives will shed additional light on the topic.

Staff from the following agencies participated in the Alameda Creek study:

1. Alameda County Flood Control District
2. ACFC&WCD Zone 7
3. Alameda County Water District
4. City of Fremont
5. East Bay Regional Park District
6. San Francisco Water Department
7. State Department of Fish and Game
8. State Department of Water Resources

The Technical Committee hopes this report will provide decision makers with the information necessary to resolve this important public policy question.

II. REQUIREMENTS FOR ALAMEDA CREEK STEELHEAD RESTORATION

A. Water Flow Requirements

The water flow requirements to support a self-sustaining run of adult steelhead in the Alameda Creek watershed depends on a sufficient amount of water being available at critical periods in the life cycle of the species (Salmo gairdneri gairdneri). Anadromous is a Greek term which means "up-running," referring to the annual upstream migration of adult fish in route to spawning areas in the same stream where they were hatched and out-migrated to the ocean to grow and mature. Returning adults have spent 1-4 years in the ocean where they grow rapidly and sometimes reach weights in excess of 15 pounds. Fertile eggs deposited in stream gravels by the adult spawners in the fall and winter, hatch in the spring. The fry generally remain in the stream environment for one to two years until they out-migrate to the ocean as "smolts" (typically 6-10 inches). Because of this anadromous lifecycle, it is possible to delineate both juvenile and adult lifestage freshwater requirements.

The major requirements of the juvenile fish in freshwater consist of: 1) water temperatures that do not exceed 72°F for prolonged periods, 2) continuous surface water flows or sufficient intermittent stream flow conditions (isolated pools) throughout the year in portions of the stream to provide rearing habitat, and 3) adequate spring to early summer (February-May 15) continuous flows to allow "out-migration" of smolts to the ocean (access to San Francisco Bay in this case).

The major adult freshwater spawning requirements consist of: 1) ability to migrate upstream to spawning areas, i.e., sufficient winter stream flows without barriers to allow upstream access, and 2) sufficient stream flow conditions at spawning sites to allow successful spawning.

In addition, such basic habitat requirements such as food and shelter are necessary for successful completion of the life cycle. These other requirements for steelhead are addressed in the Fish Habitat Restoration section that follows.

Alameda Creek watershed at one time provided all the basic flow and habitat requirements to support an adult steelhead (and probably silver salmon) migration. Figure 1 shows a number of adult steelhead harvested by workers during construction of Calaveras Reservoir completed in 1935.

By the late 1950's, however, the State Department of Fish and Game considered steelhead fishery was no longer viable in the Alameda Creek watershed. Factors contributing to their decline include water diversions and impoundments, regulation of seasonal flows, channelization (both lower on the drainage and in the Livermore-Amador Valley area), poor water quality especially due to discharges of treated sanitary wastewater (no longer a problem), and installation of permanent and seasonal migration barriers.

With respect to the three dams, no provisions were made for fish passage, nor in most cases, for water flow releases specifically to maintain fish populations and rearing areas. (Del Valle Dam being the exception as it appears live stream flows were supposed to be maintained downstream to near the

confluence with Arroyo de la Laguna as a condition of the Water Rights Permit issued by the State Water Resources Control Board (permits No. 11319 and 11320). Nonetheless, a few steelhead of unknown origin have been observed annually by DF&G and EBRPD personnel, blocked in their upstream spawning migration by a concrete drop structure (weir) constructed to stabilize the Western Pacific Railroad tracks (heretofore referred to as the WPRR Weir). The structure is located about three miles upstream from the mouth of the creek.

Currently insufficient instream data is available to predict the productivity of existing juvenile steelhead rearing habitat under different flow regimes. The preferred approach to such an evaluation of stream flow and habitat availability is the Instream Flow Incremental Method (IFIM). This essentially involves assessing available habitat (pools, riffles, glides) by making depth and cross-sectional analyses of stream reaches under a variety of flow rates during winter, spring, summer and fall conditions for at least one year. These measurements together with water flow and depth related curves developed by fishery biologists for the various lifestage requirements of the species, allow the prediction of potential productivity of the stream for juveniles and, consequently, a range of estimates for adult return spawners. Due to manpower constraints, this level of assessment has not been performed to date on the Alameda Creek watershed.

Without a broader data base using the IFIM methodology referred to above, it is not possible to predict reliable ranges of expected adult steelhead populations for existing habitat nor, for creation of additional rearing habitat. A "ballpark" prediction was made by Ken Burger, East Bay Regional Park District water management specialist, using data from the Carmel River and assuming the two streams are similar enough to make comparisons. A possibility of 2,400 adult steelhead was predicted (see Appendix C). A similar effort utilizing somewhat different sets of assumptions and methodology was performed by Dr. Chuck Hanson, fishery biologist, TENERA Consultants. Dr. Hanson predicted a range between 100-1,000 adults (Appendix C). Both of these estimates were based upon assumptions without benefit of data that the IFIM method would provide specific for Alameda Creek. Without such a detailed specific stream analysis, any adult population estimates are subject to criticism and must be regarded as best efforts without sufficient data. The need for a study to provide IFIM data for Alameda Creek is apparent.

Four alternatives are presented here. They range from no project to the minimum that must be done to allow utilization of existing spawning and rearing habitat, to the maximum potential for the restoration of the fishery. Water availability and any legal condition or requirement for flow releases to support fish and wildlife are addressed in the Water Availability section.

Alternative 1: Maintain current conditions and operation; no steelhead establishment project

This alternative would involve no new projects and would not promote establishment of a steelhead fishery. The current practice of planting 15,000 to 30,000 catchable trout each season in Alameda Creek would be continued.

The following existing conditions are not conducive to establishment of a steelhead fishery.

1. Upstream adult steelhead migration (November-March) is blocked three miles upstream from the bay by the 10 foot drop structure (weir) in the flood control channel at the Western Pacific Railroad. Migration is also hindered by inflatable rubber dams operated by ACWD in the channel and by small dams in Niles Canyon.

2. Smolts (young steelhead ready to go to sea) migrating downstream in the spring and early summer cannot reach the bay due to no provision for a continuous stream flow during critical out-migration periods.

3. Water flows to the bay have been significantly reduced due to groundwater pumping in the Livermore Valley and to dams on Alameda Creek tributaries operated by San Francisco Water Department (and to a lesser extent the California Department of Water Resources). (See Water Supply Agencies section)

4. In addition to normal seasonal runoff from the watershed, ACWD imports state water from the Delta in spring, summer, and fall. This water flows down Alameda Creek and is diverted into groundwater recharge areas before it gets to the bay. This operation supports planted trout in Niles Canyon but not a steelhead fishery since no water in most periods is allowed to flow to the bay.

5. ACWD diverts its water from the creek channel into abandoned quarry pits for percolation into the groundwater. These diversion pipes do not have fish screens. Since steelhead smolts may get diverted during migration, fish screens would be required. This is not a requirement for the existing trout fishery.

6. Table 1 summarizes this alternative.

Alternative 2: Establish a minimum steelhead fishery by constructing a steep-pass fishway at the WRPP Weir; (no minimum spring and early summer flow releases over fabridams).

Operating under this alternative, the following effects upon development of a fishery are anticipated.

1. The adult steelhead winter migration (November-March) over the WPRR Weir to remaining upstream spawning and rearing areas would occur provided Fabridam 1 is dropped periodically or the fishway is designed and constructed to allow passage over the fabridam while inflated.

   Comment: Alameda County Water District personnel have stated that normal operation of the two existing fabridams is to drop them when stream flows exceed 300-400 cfs at the beginning of major storm events. This allows poor quality (highly turbid) water to pass downstream. Steelhead would be able to pass through the fishway only at these times unless the fishway was designed to include passage over the inflated fabridam.

2. Juvenile steelhead would be reared in remaining rearing habitat identified during stream surveys conducted since 1983 consisting of about 16.5 stream miles (Appendix A). These areas include Alameda Creek (proper) through

Niles Canyon (5.5 miles) and in the vicinity of Sunol Regional Park (5.0 miles), and a 6.0 mile stretch of Arroyo Mocho east of Lake Del Valle. Tributary streams in these areas would also provide some rearing but, in general, become dry during late summer.

3. Smolts migrating downstream in the spring and early summer would be unable to reach San Francisco Bay due to lack of continuous streamflow.

   Comment: Under existing streamflow conditions, nearly all the natural runoff plus imported water from the South Bay Aqueduct (Department of Water Resources) is captured behind fabridams or stored in the Alameda Creek Quarries for groundwater percolation and replenishment of local municipal water needs. Normally there is no flow over the most downstream fabridam and, consequently, the Flood Control Channel is dry. Without a continuous flow to the San Francisco Bay during the out-migration, smolts become trapped and are unable to complete their life cycle.

4. Fish screens to prevent diversion of juvenile steelhead (smolts) into the Alameda Creek Quarries along with groundwater recharge diversions would be required by Fish and Game.

5. Continued poor returns of adult steelhead would reflect poor survival of smolts.

6. Stocking catchable trout in Niles Canyon would be discontinued.

   Comment: Fish and Game policy prohibits stocking catchable trout in steelhead streams since they would compete for the same habitat. Instead catchable trout would be stocked in one or more of the Alameda Creek Quarry lakes or channel areas west of Mission Boulevard to support a put-and-take fishery.

7. Table 1 summarizes this alternative.

Alternative 3: Establish a moderate steelhead fishery by constructing a steep-pass fishway at WPRR Weir and providing 10 cfs flow over Fabridams down a low flow channel to the bay through May 15.

Operating under this scenario the following effects upon development of a fishery are anticipated.

1. The adult steelhead winter migration over the WPRR Weir to remaining upstream spawning and rearing areas would occur provided Fabridam 1, immediately upstream of the WPRR Weir, is dropped at certain flows or the fishway is designed and constructed to include passage over the fabridam while inflated.

2. Juvenile steelhead would be reared in remaining rearing habitat (see Alternative 2, #2).

3. Out migrating smolts would be able to reach the ocean.

   Comment: In 1986 a flow of 10 cfs over the fabridams were observed to created a continuous flow to the Bay conducive to out-migration of juve-

nile smolts. Therefore the 10 cfs criterion is being applied for purposes of determining water flow requirements for out-migration. Such flows would be needed through about May 15. According to Alameda County Water field personnel, flows over the fabridams generally drop below 10 cfs by about the end of February. Water to maintain a 10 cfs flow for 2 1/2 months (March, April, May 15) would have to come from flow releases specifically allocated for this purpose from one or more of the upstream impoundments - Del Valle Reservoir, San Antonio Reservoir, and/or Calaveras Reservoir. South Bay Aqueduct water could also be used but would be less desirable due to elevated water temperatures (exceeding 72°F). Flow release towers that will permit cool water discharges from deep in the water column of each of the reservoirs are reportedly in place. Maintaining the 10 cfs flow over fabridams for approximately 76 days (March, April, May 15) would require about 1,500 acre-feet of water. Lake Del Valle, as a possible water supply source, was addressed in a reconnaissance level report (see Appendix C).

4. A self-sustaining population of adult steelhead could once again utilize remaining available habitat.

   Comment: No more than a few hundred adult steelhead could be accommodated under existing habitat conditions (i.e., without additional water flow augmentation).

5. Fish screens to prevent diversion of juvenile steelhead (smolts) into the Alameda Creek Quarries along with water diverted for groundwater recharge would be required by Fish and Game.

6. Stocking catchable trout in Niles Canyon by Fish and Game would be discontinued.

7. Table 1 summarizes this alternative.

Alternative 4: Establish a maximum steelhead fishery by constructing a steep-pass fishway at WPRR Weir; providing 10 cfs flow over fabridams down a low flow channel to the bay through May 15; and providing flow releases sufficient to maintain live streamflows downstream from reservoirs.

Operating under this scenario would approach the optimum conditions for development of a fishery by providing the following:

1. The adult steelhead winter migration over the WPRR Weir to remaining upstream spawning and rearing areas would occur provided Fabridam 1 immediately upstream of the invert is dropped at certain specified flows (300-400 cfs depending on water quality) or the fishway is designed and constructed to include passage over the inflated fabridam.

2. Juvenile steelhead would be reared in remaining habitat identified during stream surveys conducted since 1983 consisting of about 16.5 stream miles. Flow releases would augment existing (natural) summer low flows and enhance productivity (smolt production) by providing more instream habitat.

3. An additional 23.3 miles of rearing habitat downstream from the reservoir release points (Del Valle, San Antonio and Calaveras) would be created by providing continuous flows in areas that currently become dry or have elevated water temperatures (exceeding 75°F) during summer months.

   Comment: Flow releases to maintain live stream flows would have to include water losses due to evaporation, evapotranspiration and groundwater recharge. Losses due to these factors downstream from the three impoundments do not appear to be well understood. No flow data has been presented from water purveyors that would define losses. The one exception is the 1980 Urban Streams Study by the Department of Water Resources which determined that during the study period (1979-80) water losses due to these factors between Del Valle Dam and Arroyo de la Laguna, a distance of about 11 miles, resulted in losses of 13-15 cfs. Based upon those observations, it appears that in order to maintain a live stream flow from Del Valle Reservoir, flow releases would have to exceed 13-15 cfs during summer and fall periods. No data is available for similar flow losses downstream from San Antonio Reservoir or Calaveras Reservoir. However, surface flows due to natural runoff have been observed downstream of Calaveras Reservoir to the vicinity of Naka Nursery during the summers of 1986-88. Only about 3-3.5 miles of dry stream bed existed before confluence with Arroyo de la Laguna where streamflows are perennial. This would imply that flow losses may be significantly less than the 13-15 cfs losses observed for Del Valle releases. In order to arrive at flow releases necessary to provide live stream flows downstream from impoundments, flow experiments appear to be necessary. A similar steelhead restoration effort for the Carmel River, where two water supply reservoirs have seriously affected normal streamflow conditions, resulted in an agreement to provide 5 cfs minimum flow to accommodate habitat requirements of steelhead. During critical water years such as 1986-87 a flow of 3 cfs was negotiated under the concept that water availability for all the various beneficial uses varies from year to year. A similar strategy could be adopted to the Alameda Creek watershed.

4. Out-migrating smolts would be able to reach the ocean via a low flow channel (maintained annually as required).

5. A larger self-sustaining population of adult steelhead could be supported by remaining and expanded rearing habitat than would result from Alternative 3 above.

6. Fish screens to prevent diversion of juvenile steelhead (smolts) into the Alameda Creek Quarries along with water diverted for groundwater recharge would be required by Fish and Game.

7. Stocking catchable trout in Niles Canyon by Fish and Game would be discontinued.

8. Table 1 summarizes this alternative.

B. Fish Habitat Restoration

An important element in the overall effort to restore a self-sustaining run of adult steelhead in Alameda Creek will be fish habitat restoration. Enhance-

ment of the remaining habitat will increase smolt production and consequently increase the number of returning adults. The prior section on water flow requirements has already addressed several habitat restoration issues, i.e., water flows for fish passage and rearing and spawning habitat.

Steelhead, like other fishes, require more than the mere presence of water to survive. The following is a list of factors that must be present in order to sustain a migratory steelhead run in the Alameda Creek watershed.

1. Food: Food sources are primarily aquatic insect larvae and adults such as stoneflies, mayflies, caddisflies, etc., that are familiar inhabitants on and beneath stream rocks, cobbles and woody debris.

   Insects falling from streamside vegetation can also be an important source of food.

2. Shelter: It is important to provide refuges for juvenile fish to escape from predators such as raccoons or other predatory species of fish. Refuges also provide microhabitat where water temperatures are cooler than the ambient surrounding water allowing the fish to survive periods of elevated water temperatures that would otherwise be lethal. Shelter is typically provided by undercut banks, tree root masses, and undersides of large rocks and boulders or bedrock crevices.

3. Riparian plant species, i.e., plants growing in and immediately adjacent to the stream channel, provide food through insect drop (drift) as well as shade that can prevent high water temperatures.

4. Opportunity to reproduce: The opportunity to reproduce includes adequate streamflow to provide sufficient water depths during the spawning process and to keep the eggs moist and well oxygenated while they are incubating in the gravel where they are deposited. Gravels must be of sufficient size (mix of 1/4 - 3 inch diameter) and relatively silt free to be useable (otherwise eggs will suffocate).

The field of stream and fish habitat restoration has blossomed in recent years as interest in stream restoration has gained momentum across the country. Technologies for different aspects of instream restoration are still developing. A partial list of techniques and their benefits are:

1. Planting riparian plant species - use of alders, willows and other easily established plant species are effective at providing stream shading to prevent elevated water temperatures and provides drift as a food source. They are also effective for use in stabilizing banks to prevent erosion. Considerable planting is needed through the watershed.

2. Installation of gabions - these rock filled wire baskets can be installed within the stream to form weirs for collection and stabilization of spawning size gravels, to create shelter and pools and can be located along unstable banks as protection from erosive water flow velocities.

3. Installation of log weirs - logs along or within the stream environment can be used to perform the same functions as gabions but are much cheaper to install. Figures II-A and II-B show a typical log weir installation.

4. Removal of severe debris jams - physical removal of severe debris jams will allow fish migration that might otherwise be blocked.

5. Modification of instream permanent migration barriers - the WPRR Weir is a classic example of a complete barrier to upstream migration. Construction of a steep-pass fishway is recommended.

6. Installation of fish screens - for major stream flow diversions such as Alameda Quarry pond groundwater recharge diversions, installation of fine mesh screens at pipe inlets to prevent entrapment of juvenile steelhead may be necessary.

A long-term fish habitat restoration plan that addresses specific areas within the watershed is needed. Inputs from stream surveys already conducted as well as from a more detailed stream evaluation provided by an IFIM study could be the basis for the plan. The following elements would be important aspects of the restoration plan.

1. Modification of the in-stream fish passage barriers at the WPRR Weir to allow upstream access to remaining spawning and rearing habitat.

2. Encourage initial plantings of yearling juvenile steelhead, preferably of East Bay native stock, to help restore a viable adult spawning population within the watershed at the earliest possible time.

3. Freshwater habitat improvement efforts including but not limited to, restoration of riparian vegetation throughout the drainage, manipulation of pool to riffle ratios utilizing instream techniques, initiation of summer critical flow augmentation if available, and general evaluation of the watershed to find ways to enhance freshwater requirements of adults and juvenile steelhead.

4. Involve local sportsmen's groups, organizations, and public participation, in general, including "hands-on" projects directed toward habitat restoration.

5. Solicit funds from government agencies and private businesses to finance all aspects of the steelhead restoration effort.

6. Encourage adoption of special regulations by the Fish and Game Commission to protect juvenile and adult steelhead until the run is significantly restored to allow regulated harvest of the resource.

7. Development of a comprehensive management plant that will include important fishery management issues such as: a) agency coordination, b) habitat protection, c) habitat improvement, d) fish population enhancement, and e) public education.

C. Funding Sources

Precise costs for the steelhead restoration project are unknown at this time and will vary depending on a number of factors including the number and extent of areas along the stream that receive habitat improvement treatments, the

level of monetary and other support attracted from private industry as well as methods and techniques utilized. However, the costs for the first phase restoration effort, i.e., construction of a fishway over the WPRR Weir, can be estimated at this time based upon prior project costs and evaluation by Ted Vande Sande, Fish and Game hydrologic engineer. An estimate of $5,000-$10,000 per vertical foot rise is the guideline utilized based upon projects of similar nature. Since the drop structure (WPRR Weir) poses about a 10 ft. vertical barrier, costs should be $50,000-$100,000 for this important step.

Other costs for fish screens and habitat restoration (see Table 2) also would need funding.

Potential sources of grant funding identified through programs administered by the State Department of Fish and Game include:

1988-1989 Fiscal Year Amounts

1. Bosco-Keene - $630,000 available for various stream restoration or rehabilitation projects.

2. Proposition 19 - $2,000,000 available for flowing waterways for the management of fish, habitat for wildfowl, marshlands, habitat for threatened, endangered and fully protected species.

3. AB 1705 - $5,000,000 available for restoration of fishery resources and habitat damaged by past water diversions, acquisition of land, restoration of habitat, restoration or creation of spawning areas, artificial reef construction, construction of fish screens or fish ladders, stream rehabilitation and installation of pollution control facilities.

In addition, if the California Wildlife Coastal and Park Land Conservation Act (CALPAW) initiative being placed on the ballot this June is passed by the voters it will include:

1. $17,000,000 for fisheries (California Fish & Game)

2. $5,000,000 for urban stream restoration (Department of Water Resources)

D. Unresolved Questions: Section III, Requirements for a Fishery

Some members of the committee have concern that the above requirements for a steelhead fishery and the projected success of a steelhead fishery are based on insufficient data. Following are some questions raised which would require an IFIM study to resolve.

1. On what basis can reliable ranges of expected adult steelhead populations be predicted?

2. Are existing stream bed conditions conducive to spawning?

3. Will flushing flows be necessary to create optimum spawning gravel conditions?

4. What amount of flow is required for upstream rearing habitat? Wouldn't an IFIM study would help to determine the carrying capacity of stream-related substrate, food and flow.

5. Wouldn't an evaluation of the effect of flow fluctuations on potential spawning success be needed?

6. How many years would an effective IFIM study take? How much would it cost? Who will pay for it? Where will the water come from?

Additional Questions Relating to a Fishery in General:

1. What is the effect of delta water being imported into the creek (temperature, scent)?

2. Do the current estimates of production take into account the extremely variable hydrologic conditions in the watershed?

3. From an operations standpoint can SFWD release enough cool water to permit steelhead to survive without excessive mortality? Does the watershed have enough natural features (e.g., undercut banks) which would prevent mortality due to high temperatures?

4. How much water will the new riparian vegetation consume?

5. The report states that one of the major spawning requirements is sufficient water flows without barriers. Would additional winter releases of water be necessary, given the fact that SFWD reservoirs rarely spill? How much water would be required for this purpose, in addition to the March 1-October 15 releases proposed in Alternatives 3 and 4?

6. Who will pay for the installation and maintenance costs of fishways and screens? The report identifies up to $560,000 installation and $100,000 annual maintenance costs. Is the cost estimate for construction of the three plunge pools ($60,000) below the ACWD fabridams accurate?

7. How much will construction of the low flow channel in the Alameda Creek Flood Control Channel cost? The report states that 4.5 miles of channel would be required at a $2,000 annual maintenance cost. Is this a realistic estimate? What amount of silt is carried by Alameda Creek each year? Will various entities involved with approving such a project (e.g., U.S. Army Corps of Engineers) approve it?

8. What impact will flood flows have on proposed habitat restoration projects (e.g., log weirs)?

9. Is it accurate to transfer IFIM studies on the Carmel River to Alameda Creek, given differences in hydrology and habitat?

10. Detailed recreational value studies should be conducted to give justification to the costs here versus using the money elsewhere. Who will pay for any recreational studies, and how much will they cost?

11. Is the recreational value of the existing catch and release trout fishery necessarily less than a steelhead fishery? How can the relative values be compared without a recreational cost-benefit analysis? Is it worth eliminating much of the trout fishery to create a limited steelhead fishery with minimal, if ever, harvest potential?

12. How much water would be needed to create a 10 cfs flow over the most downstream fabridam? What losses could be expected from percolation, evaporation and evapotranspiration?

13. Would spills from dams, although infrequent, harm the fishery?

14. How accurate is the extrapolation of percolation losses on Arroyo De Laguna over to Calaveras and Alameda Creeks? How does the geology of Arroyo de la Laguna compare to Alameda Creek? Are the 13-15 cfs percolation losses observed on Arroyo de la Laguna equal to the losses which could be expected on Alameda Creek?

15. Is it accurate to presume that because summer flows exist downstream from Calaveras Dam to the vicinity of Naka Nursery, that percolation losses on Alameda Creek would be less than the 13-15 cfs losses observed on Arroyo de la Laguna?

16. Who will pay for the cost of releasing 20 cfs under alternative 3? Is this figure sufficient to create a 10 cfs flow over the last ACWD fabridam several miles downstream?

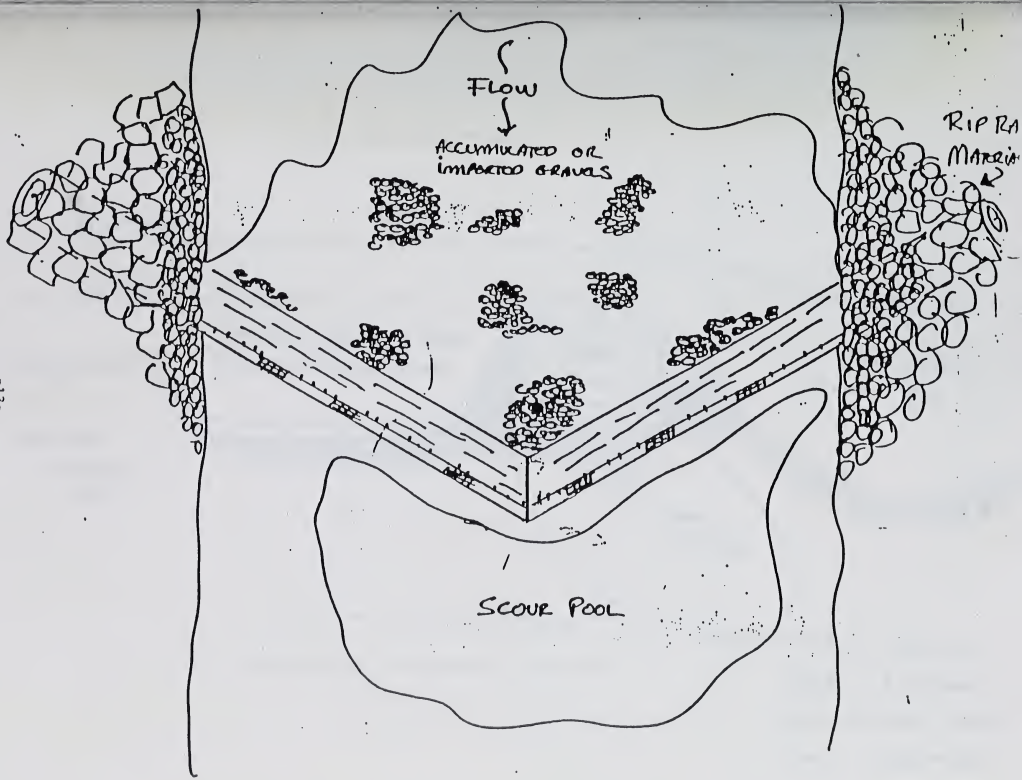

FIGURE II-A Top view of completed log weir structure.

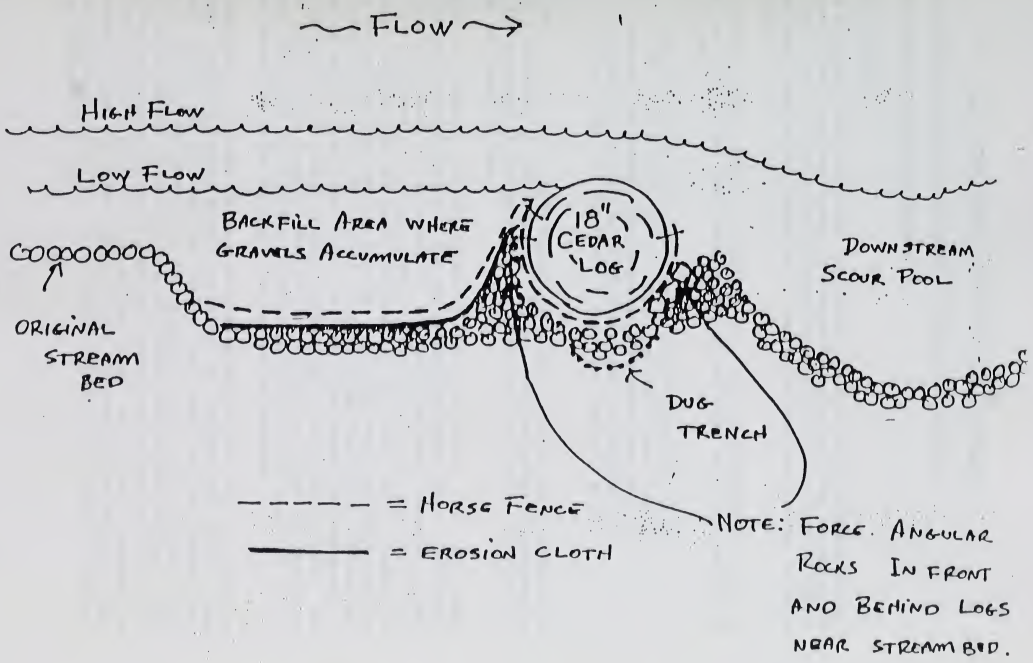

FIGURE II-8 Cross sectional view of log weir structure.

b. Local Water

As originally designed, Calaveras Reservoir (construction completed in 1925) stored water for controlled release into Alameda Creek. This controlled release recharged extremely permeable gravel beds (currently located immediately south of Interstate 680 in the Sunol Valley) which were tapped by the Sunol filter galleries. Water from the Sunol filter galleries in turn supplied the Sunol Aqueduct via the Sunol Water Temple. The Sunol Aqueduct carried the water by gravity through Niles Canyon to the Niles Reservoir, from where it flowed into the Niles Irvington pipeline to the Irvington pump station. From here the water was pumped across San Francisco Bay in the Bay Division pipeline and carried to Crystal Springs Reservoir and ultimately San Francisco.

TABLE III-A

HISTORICAL RECORDS OF SPILLS FROM CALAVERAS RESERVOIR

Year	Period	Amount, Millions of Gallons	Amount Acre-Feet
1938	February 11 - March 27	No record	No record
1941	February 17 - April 18	No record	No record
1952	January 12 - May 21	28,900	88,720
1956	January 19 - May 1	14,780	45,370
1958	March 17 - May 25	20,090	61,670
1965	April 11 - May 5	4,350	13,360
1967	April 3 - May 26	9,150	28,090
1969	February 25 - May 7	8,650	26,360
1970	March 1 - April 7	2,480	7,610
1973	February 28 - March 26	2,260	6,940
1983	January 27 - May 24	31,170	93,690
1986	February 19 - April 9	13,330	40,920

Calaveras Reservoir, located on the Calaveras and Arroyo Hondo Creeks, has a drainage area of about 100 square miles. Its supplies are supplemented by water from the Alameda Creek drainage which is diverted to the reservoir via the upper Alameda Creek Diversion Dam and Tunnel. Calaveras Reservoir currently delivers water by gravity through the Sunol Water Treatment Plant. San Antonio Reservoir also supplies water to the Sunol Treatment Plant, but water must be pumped via the San Antonio Pump Station. Treated water from the Sunol plant is discharged directly into the Hetch Hetchy aqueduct lines that cross the Sunol Valley, also known as the "Alameda Creek siphons." Controlled releases from Calaveras Dam no longer occur since the water is now treated at the Sunol filter plant. Any water which percolates into the Sunol filter galleries via the gravel beds is pumped to San Antonio Reservoir using the Sunol pump station. The Sunol Aqueduct currently supplies the SFWD's retail customers located in Niles Canyon.

The SFWD's water rights for Calaveras Reservoir and the Alameda Diversion Dam predate the State of California permit system. (Pre-1914 rights) San Antonio Reservoir was built after 1914. At the time San Antonio Reservoir was approved in 1961, the California Department of Fish and Game ("CDFG") expressed concern for the use of water for fish and wildlife purposes in San Antonio Creek. After a review, the CDFG concluded that the reservoir would not have a detrimental impact on downstream fish and wildlife.

Turner Dam, which forms San Antonio Reservoir, was completed in 1965. San Antonio Reservoir, located on La Costa (San Antonio) Creek, has a very small watershed that supplies intermittent storm runoff. It is used to store Calaveras Reservoir water and Hetch Hetchy water for treatment at the Sunol Treatment Plant, which then becomes part of the Bay Area treated water supply. San Antonio Reservoir is subject to the same Raker Act restrictions as the City's other local facilities; the restriction on maximum use of local water perhaps applies to a greater degree to San Antonio Reservoir as a portion of its waters are from Hetch Hetchy.

Releases from Calaveras Reservoir would be subject to undetermined losses due to percolation from Alameda Creek and the Sunol Valley. There would be some evapotranspiration losses in the normally dry creek. Channel percolation of the groundwater could cause rising water levels in the quarry pits and a subsequent conflict with the quarry operations.

2. California Department of Water Resources

The California Department of Water Resources operates the State Water Project which supplies water to 30 agencies throughout the state. Three of the agencies are ACWD, Zone 7 and Santa Clara Valley Water District (South Bay Contractors).

The State supplies State Project water to the South Bay Contractors through the South Bay aqueduct which includes Lake Del Valle. The State also operates Lake Del Valle to capture, store and release local runoff water for Zone 7 and ACWD which have local water rights on the Arroyo del Valle.

The State Water Project is water supply deficient and is expected to remain so indefinitely. Therefore the State will not allocate a part of its water supply for steelhead restoration in Alameda Creek.

ACWD and Zone 7 have entitlements to State Project water; however, as growth takes place this water supply will be fully utilized. This water is primarily used for municipal and industrial purposes with a small amount used for irrigation agriculture.

Lake Del Valle local water is shared by Zone 7 and ACWD. Part of the water is used for groundwater recharge and part of it is treated for distribution within the two agencies' service areas. The Del Valle water is an intermittent supply depending on the weather, operation of Lake Del Valle and on the needs of the two water districts.

Lake Del Valle water is transported in the South Bay Aqueduct to the treatment plants and to turnouts for release into tributaries of Alameda Creek for groundwater recharge. Releases at the Arroyo del Valle turnout flow down Arroyo Del Valle through Pleasanton and into Arroyo de la Laguna, then into Alameda Creek. Water taken along this route conflicts with Zone 7 operating goals and with Pleasanton quarry operations for the next 30 or so years. ACWD is concerned about water losses by importing water through this route.

3. Alameda County Water District

The Alameda County Water District serves the area within the cities of Fremont, Newark, and Union City. The service area has a population of about 255,000 persons and covers approximately 100 square miles. The ACWD service area is shown on Figure III-B.

The District supplies potable water to the residents of the three cities. It manages the Niles Cone groundwater basin from which private pumpers draw water for industrial use, municipal recreational use and agricultural irrigation.

Currently, the ACWD distribution system supplies are about 30 percent from San Francisco, 20 percent treated State Project water and 50 percent pumped groundwater. The groundwater is recharged with local water and imported State Project water. The ratio of these two sources varies with climatic conditions.

The District expects all of its water supplies to be fully utilized in the next decade. ACWD is implementing its Capital Improvement Program which includes facilities to increase its local supplies so as to provide for the increases in demands it anticipates will take place in the next 10 to 15 years. Even with these supplies, water restrictions will be required during droughts.

4. Zone 7 of Alameda County Flood Control and Water Conservation District

Zone 7 of Alameda County Flood Control and Water Conservation District is the water resources manager for the area upstream of the confluence of Alameda Creek and Arroyo de la laguna. The Zone 7 service area is shown on Figure III-C. Zone imports water from the State Water Project through the South Bay

Aqueduct. The major portion of imported water is treated at two treatment plants and delivered to retailers in Dublin, Livermore and Pleasanton for distribution to the consumer. A small portion (10 percent) is used for agricultural purposes.

In addition to the imported water, Zone 7 has local water rights (in partnership with Alameda County Water District) on the Arroyo del Valle. This water is generally captured in Lake Del Valle. Some of that water is released and recharged into the Zone's groundwater basin. The remainder is generally processed at its water treatment plants and distributed within its 120,000 population service area.

Zone 7's groundwater resources are fairly extensive. However, the average annual yield is only about 13,000 acre-feet, and it is being fully used. If excess pumping were to commence, then that excess would have to be replaced during years of excess supply.

As a whole the various supplies will be more fully utilized in another 20 or so years. It is expected that additional developed water will then be needed to sustain a successful, growing community.

5. Alameda County Flood Control and Water Conservation District

The Alameda County Flood Control and Water Conservation District (ACFC) provides flood control facilities and maintenance throughout Alameda County. It cooperates with the Corps of Engineers and State agencies in providing this service. ACFC regularly performs maintenance in the Alameda Creek Flood Control Channel to regrade the channel bottom and remove debris.

Zone 7 is the only area within ACFC&WCD with a water supply and Zone 7 is governed by its own Board of Directors. ACFC&WCD does not have any water supplies that it controls in other areas of Alameda County.

B. Required Improvements, Facilities Modifications and Operational Changes

As discussed in the "Requirements for a Fishery" section of this report, four steelhead restoration alternatives have been presented. This section will identify the required improvements, modifications to existing facilities, and changes in water handling operations that would be required to support a water supply for each of the steelhead establishment alternatives.

1. ALTERNATIVE 1 - Maintain current conditions and operation

   a. No physical improvements are required.

   b. No modifications to existing facilities are required.

   c. No changes in existing water handling operations are required.

2. ALTERNATIVE 2 - Construct Fishway at WPRR Weir, (drop structure)

   a. Installation of a fishway would be required at the Alameda Creek Flood Control Channel drop structure located at Army Corps of

Engineers Station 519+52+, between the Union (Western) Pacific Railroad and the BART crossings of the Alameda Creek Flood Control Channel. Regular maintenance and eventual replacement of the fishway would also be required.

As shown in Table 2, the capital cost for a fishway is estimated to range between $75,000 to $125,000. The annual maintenance and replacement cost is estimated to range between $9,000 to $14,000.

b. Installation of fish screens would be required pursuant to California Department of Fish and Game Standards ("General Fish Screening Criteria, Appendix F") for at least six of ACWD's existing and proposed water diversion facilities in the Alameda Creek Flood Control Channel.

As shown in Table 2, the capital cost for fish screens, depending on screen type (i.e., self cleaning), ranges from a low of $90,000 to a high of $870,000. The annual maintenance and replacement cost is estimated to range between $8,000 and $77,000.

c. Construction of plunge pools would be required immediately downstream of each of ACWD's inflatable dams to protect smolts from injury during overfall.

The estimated capital cost for constructing three pools is $60,000.

d. ACWD would be required to deflate each of its three (two existing and one proposed) inflatable dams four times during the period November 1 through February 28 to accommodate upstream migration of adult fish. In some years this may happen naturally due to flood flows.

This operation, in addition to releasing approximately 1,500 acre-feet of water per year to SF Bay, would cost up to $4,000 per year.

e. ACWD would be required to make the following operational changes to accommodate emigrating smolts:

(1) Provide overflow at inflatable dams when excess water is available.

(2) Delay annual construction of two temporary earthen dikes (Dike 8 and Dike 9 located within the Alameda Creek Flood Control Channel) until after May 15.

(3) Regulate water diversion flow rates during the period March 1 through May 15 to meet the CDF&G minimum velocity requirements at the fish screens.

3. ALTERNATIVE 3 - Construct fishway and provide 10 cfs minimum flow over inflatable dams during the smolt emigration period March 1 through May 15.

a. Construct fishway (See Alternative 2).

As shown in Table 2, the capital cost for a fishway is estimated to range between $75,000 to $125,000. The annual maintenance and replacement cost is estimated to range between $9,000 to $14,000.

b. Install fishscreens (See Alternative 2).

As shown in Table 2, the capital cost for fish screens, depending on screen type (i.e., self cleaning), ranges from a low of $90,000 to a high of $870,000. The annual maintenance and replacement cost is estimated to range between $8,000 and $77,000.

c. Construct plunge pools (See Alternative 2).

The estimated capital cost for constructing three pools is $60,000.

d. Deflate rubber dams (See Alternative 2).

This operation, in addition to releasing approximately 1,500 acre-feet of water per year to SF Bay, would cost up to $4,000 per year.

e. Make operational changes (See Alternative 2).

f. Construction and maintenance of a low flow channel would be required within the Alameda Creek Flood Control Channel, between the downstream inflatable dam (Fabridam No. 2) and the San Francisco Bay tidal zone. This low flow channel is needed to accommodate emigrating smolts during the period March 1 through May 15.

The estimated minimum annual cost for maintaining approximately 4.5 miles of low flow channel is $2,000 per year.

g. It is estimated that ensuring 10 cfs flow over ACWD's downstream inflatable dam (Fabridam No. 2) during the period March 1 through May 15 would require at minimum one of the following:

(1) an estimated 12 cfs flow release (about 1,800 acre-feet) from the South Bay Aqueduct Vallecitos Turnout.

(2) An estimated 20 cfs flow release (about 3,000 acre-feet) from either the San Antonio Reservoir or the Calaveras Reservoir.

(3) An estimated 25 cfs flow release (about 3,800 acre-feet) from either the South Bay Aqueduct Arroyo Valle turnout or Lake del Valle directly.

The above figures must be significantly increased if releases are not concurrent with ACWD's import of State water.

4. ALTERNATIVE 4 - Construct fishway, provide 10 cfs minimum flow over inflatable dams during the smolt emigration period March 1 through May 15 and provide live stream flows downstream from reservoirs.

   a. Construct fishway (See Alternative 2).

      As shown in Table 2, the capital cost for a fishway is estimated to range between $75,000 to $125,000. The annual maintenance and replacement cost is estimated to range between $9,000 to $14,000.

   b. Install fishscreens (See Alternative 2).

      As shown in Table 2, the capital cost for fish screens, depending on screen type (i.e., self cleaning), ranges from a low of $90,000 to a high of $870,000. The annual maintenance and replacement cost is estimated to range between $8,000 and $77,000.

   c. Construct plunge pools (See Alternative 2).

      The estimated capital cost for constructing three pools is $60,000.

   d. Deflate rubber dams (See Alternative 2).

      This operation, in addition to releasing approximately 1,500 acre-feet of water per year to SF Bay, would cost up to $4,000 per year.

   e. Make operational changes (See Alternative 2).

   f. Construct low flow channel (See Alternative 3).

      The estimated minimum annual cost for maintaining approximately 4.5 miles of low flow channel is $2,000 per year.

   g. Release water from March 1 to May 1 (See Alternative 3).

   h. Ensure a live stream (5 cfs minimum flow) in Arroyo del Valle between Del Valle Dam and confluence of Arroyo de la Laguna by securing a flow release of about 20 cfs from either the South Bay Aqueduct Arroyo Valle turnout or Lake del Valle directly, during the period May 15 through October 30 (169 days). The annual water requirement for this live stream will be about 6,700 acre-feet.

   i. Ensure a live stream (5 cfs minimum flow) in Alameda Creek between Calaveras Dam and confluence of Arroyo de la Laguna by securing a flow release of about 15 cfs from Calaveras Reservoir during the period of May 15 through October 30 (169 days). The annual water requirement for this live stream will be about 5,000 acre-feet.

   j. Construct and maintain additional rearing habitat. No costs have been estimated. Materials are expected to be donated. Labor is expected to come from volunteer groups.

TABLE 2

SUMMARY OF COSTS OF IMPROVEMENTS

FISHWAY

LOCATION: ALAMEDA CREEK FLOOD CONTROL CHANNEL (C.O.E. Station 519+52±)
TYPE: Steep pass
USEFUL LIFE: 20 Years
ESTIMATED CAPITAL COST $75,000 to $125,000
ESTIMATED REPLACEMENT COST (A): $ 7,100/yr to $ 11,800/yr
ESTIMATED MAINTENANCE COST (A) $ 1,400/yr to $ 2,400/yr

FISHSCREENS

WATER DIVERSION FACILITY REQUIRING FISHSCREEN	1988 STATUS	OWNER	OPERATOR	REMOVABLE SCREEN (C) ESTIMATED CAPITAL COST ($000)	REMOVABLE SCREEN (C) ESTIMATED ANNUAL REPLACEMENT & MAINTENANCE COST (B) ($000)	FIXED/MECHANICALLY CLEANED SCREEN ESTIMATED CAPITAL COST ($000)	FIXED/MECHANICALLY CLEANED SCREEN ESTIMATED ANNUAL REPLACEMENT MAINTENANCE COST (B) ($000)
Alameda Creek Pipeline Intake	Existing	ACWD	ACWD	10-20	1-2	50-100	4.4- 8.8
Bunting Pit Pump Intake	Existing	ACWD	ACWD	5-10	0.5-1	25- 50	2.2- 4.4
Kaiser Pit (AHF) Intake	Existing	ACWD	ACWD	5-10	0.5-1	25- 50	2.2- 4.4
Shinn Pit Intake	Existing	ACWD	ACWD	15-25	1.3-2.2	60-120	5.3-10.6
Pit T Intake	Existing	ACWD	ACWD	5-10	0.5-1	25- 50	2.2- 4.4
Pit S Intake	Proposed	ACWD	ACWD	50-100	4.4-8.8	250-500	22.1-44.3

(A) = Equivalent Uniform Annual Cost for n = 20 years, i = 7%
(B) = Equivalent Uniform Annual Cost for n = 30 years, i = 7%
(C) = Rate of water diversion flow v minimum velocity requirements which may be imposed by DF&G criteria could limit use of this type of screen

III.C. Questions and Unresolved Issues

1. The water suppliers determine that all available sources of water in the Alameda Creek watershed (local and imported) are, or will in the future, be committed to three beneficial uses (i.e., domestic, municipal, and agricultural (minor amount)). No water is perceived to be available for other uses including fish and wildlife or recreation, (except for some mutually beneficial uses which do not in any way adversely affect or reduce the agency's water supply). Does the sentence "San Francisco Water Department's water supplies are fully committed and there is serious concern over violation of the Raker Act." mean that all available water is currently being used or that anticipated future demands will result in complete use? How much water normally available (stored) is not being used for municipal and domestic purposes? What percentage of the normal watershed runoff is released below the dam?

   The concern over violation of the Raker Act appears not to be well founded. The last paragraph of the Act clearly establishes that State law has precedence, and full compliance with State laws is required as a condition and implementation of the Act.

   Fish and Game Code Section 5937 requires sufficient flows downstream from dams and water impoundments to maintain fish and wildlife. Such flow releases are not being made.

2. The Water Suppliers state "There is no water available from the State Water Project for fishery enhancement in Alameda Creek." However, State Water Project water has been made available elsewhere as a recreational component and for fish and wildlife purposes in recognition of these other beneficial uses of water established by State law. The TAC should formally apply to the State for allocation of water to allow flow releases in the Alameda Creek watershed to support the steelhead restoration.

3. The Water Suppliers state "Releases at the Arroyo del Valle turnout flow down Arroyo del Valle through Pleasanton and into Arroyo de la Laguna, then into Alameda Creek. Water taken along this route conflicts with Zone 7 operating goals and with Pleasanton quarry operations for the next 30 years or so." Apparently flow releases into Arroyo del Valle from the Del Valle Dam are not being made on a regular, continual basis. This appears to be a violation of the water right permit issued by the State.

   As a condition of Water Rights Permit 11319 affecting water storage at Del Valle Reservoir, the State Department of Fish and Game filed a protest to protect game and non-game species of fish located downstream from the dam. The negotiated settlement of this protest and a condition of Permit 11319, specifies: "Permittee shall, concordant with project operational procedures and objectives, maintain a live, flowing stream in the reach of Arroyo del Valle from Del Valle Dam to the USGS Gaging Station 11-1766 on Arroyo del Valle near the confluence with Arroyo de la Laguna when water stored pursuant to this permit is available."

   It appears that water flow releases from Del Valle Dam are always available in that the lake always contains stored water.

Regular flow releases were made initially until 1983 when an agreement was reportedly made with the quarry operators to discontinue flow releases, preventing groundwater recharge from interfering with quarrying operations. This agreement with quarry operators should not invalidate the separate prior permit requirement to make continual releases.

4. The Water Suppliers state "ACWD and Zone 7 have entitlements to State Project water, however, as growth takes place this water supply will be fully utilized." However, at a recent meeting involving EBRPD and Zone 7, EBRPD was advised that Zone 7 has a very optimistic future regarding water supply for its service area. If its entitlements from the State Water Project are fulfilled, the water supply for that area will exceed all projected demands based upon the General Plan for local government. It was mentioned that surplus water may be great enough to sell some of it to other contractors. It would be helpful if data regarding current and future demands based upon existing General Plan documents was provided by ACWD, Zone 7, other South Bay Aqueduct contractors, and San Francisco Water Department. Existing State Water Project contract entitlements should be included with a prospectus on percentage of entitlements that will be provided in the future (if not already met).

5. The Water Suppliers state "Calaveras Reservoir water rights and commencement of dam construction are pre 1914, and not bound by the State of California permit system." Has the San Francisco Water Department resolved the issue with the State Board as to whether a permit to store water at the site of the Calaveras Reservoir should be obtained? (Note: During the 1959 State Board hearings regarding water rights at San Antonio Reservoir, the State Board determined that since no permit was obtained "the Board would apparently be required to regard the Calaveras Reservoir operation as unauthorized (Water Code Section 1225) and the water therein stored and used as still subject to appropriation.")

   Although the water rights for the Calaveras Reservoir are pre 1914, has the water storage within the reservoir increased and has the water usage increased significantly since 1914?

6. The Water Suppliers state "At the time San Antonio Reservoir was constructed in 1964, dialogue with the Fish and Game took place concerning the fishery of San Antonio Creek. After review, the Fish and Game withdrew their protest stating that the Reservoir would not have a detrimental effect on downstream fishery." The Department of Fish and Game considered the self-sustaining run of steelhead to be extirpated in the Alameda Creek watershed by the mid 1950's due to habitat degradation and flow manipulation practices. Now, however, the Department of Fish and Game is under a legislative directive to examine restoration of historical steelhead runs and now supports restoration of the steelhead fishery in the Alameda Creek watershed along with flow releases to accommodate this effort.

The Appellate Court "Racanelli Decision" (U.S. vs. State Water Resources Control Board, May 1986) establishes authority of the State to review all existing water rights permits to assure the public trust doctrine and that all beneficial uses were properly considered before issuance of the permit. Permit conditions may be changed to reflect conformance with the public trust. It does not appear that the public's interest and reasonable protection of all beneficial uses has prevailed in the Alameda Creek watershed.

TABLE IV SUMMARY OF STEELHEAD ESTABLISHMENT PROJECT ALTERNATIVES

ALTERNATIVES	1 - No Project	2 - Minimum Project	3 - Moderate Project	4 - Maximum Project
	o Current Conditions	o Construct Fishway	o Construct Fishway o 10 CFS Flow over Fabridam #2 from March 1 through May 15	o Construct Fishway o 10 CFS Flow over Fabridam #2 from March 1 through May 15 o Live stream below Reservoirs
CONDITIONS				
1. Barrier to adult migration	Yes	No	No	No
2. Existing rearing habitat	N/A	16.5 miles estimated	16.5 miles estimated	16.5 miles estimated
3. Additional rearing habitat	None	None	None	23.3 miles estimated
4. Smolt "Out-Migration" assured	No	No	Yes	Yes
5. Fish screens/Plunge Pools required	No	Yes	Yes	Yes
6. Adult migration	N/A	Poor	Self-sustaining	Larger Self-sustaining
7. Put-and-take trout fishery in Alameda Creek east of Mission Blvd.	Yes	No	No	No
8. Steelhead harvest	No	*	*	*
COST ESTIMATES				
First Year Capital	-0-	$225,000 to $1,055,000	$225,000 to $1,055,000	$225,000 to $1,055,000
Annual M & R	-0-	$ 16,000 to $ 91,000	$ 19,000 to $ 93,000	$ 19,000 to $ 93,000
Annual Water	-0-	-0-	$ 45,000 to $ 760,000	$145,000 to $3,100,000

* fishing limited (i.e., none until established, or catch and release; limited harvest once established)

V. COMMENTARY

This commentary section is provided as a vehicle for Technical Committee members to articulate perspectives which, though important to the policy considerations, would not be appropriate in the strictly technical assessment portion of the report.

A. Environmental Perspective

The Alameda Creek watershed is the largest watershed on the east side of San Francisco Bay draining a land mass of nearly 700 square miles. Like other coastal streams of its size in central and southern California, as far south as Santa Barbara and north to Eureka, it naturally becomes nearly dry (except in the headwaters) during summer months and drought periods; yet once supported a viable run of steelhead trout.

Actual historical numbers are not known for this watershed or any other streams in California. Early data on this resource, in most cases, is simply not available. The best estimate comes from visual observations and recollections of "old timers" who used to frequent the watershed in pursuit of the fish. Early accounts by locals indicate that a substantial number of steelhead ascended the Alameda Creek watershed annually. Angling for steelhead was not uncommon into the 1950's. During construction of Calaveras Reservoir, completed in 1935, steelhead were plentiful enough that workmen harvested them on their spawning grounds as evidenced by photographs depicting stringers of steelhead. Recent photographs (in possession of Fish and Game) are also available of steelhead that were able to ascend Alameda Creek as far as the WPRR Weir (also called BART invert) located only 3 miles from the mouth. The complete barrier at the WPRR Weir prevents further upstream access necessary to complete spawning, thereby perpetuating the species.

Like so many streams, Alameda Creek has been degraded so severely by man's activities that it no longer supports a viable run of steelhead. Currently best estimates by Fish and Game indicate that the steelhead resource in California has dwindled to about 20 percent of estimated numbers that existed there in the 1950's. This statewide crisis was so apparent to sportsmen and environmental groups as well as State resource agencies, that the State Legislature responded in 1983 by issuing a directive to Fish and Game to develop a plan to restore the steelhead (and salmon) resources throughout the state in streams that historically supported steelhead runs. In the 1970's, Alameda Creek was identified by the State Department of Water Resources as the top candidate of all urban streams surveyed within the entire state that could be restored to support a viable fishery. That agency also recognized that in order to do this, cooperation among all the agencies with water interests would be necessary. Consequently, interest by local sportsmen's groups and resource agencies continued and has culminated in this Technical Advisory Committee Report.

The report has described what would be necessary in terms of fish migration barrier modification, cooperative water management to provide water for all the beneficial uses including reestablishment of a steelhead fishery, and potential for habitat enhancement, all of which are necessary due to the current degraded nature of the streams within the watershed.

It has been shown (in fact, design sketches have already been made) that installation of a fishway over the WPRR Weir is technically feasible and is the only complete barrier currently preventing access to spawning grounds. It has been shown through stream surveys that viable habitat for rearing young steelhead still exists. It has been shown that this habitat could be enhanced by instream techniques with major labor supplied by volunteer groups. It has been shown that the amount of water necessary to restore the fishery is not unreasonable (1,800-3,800 acre-feet of water for alternative 3 or about 7 percent of the average natural water yield in the Calaveras Reservoir watershed alone). It has been shown that certain legal agreements (Water Rights Permits and Fish and Game Code Section 5650), and requirements to release water to protect downstream fishery resources located below the dams in the watershed have been ignored. It has been shown that the concept of the public trust doctrine being used more and more frequently in reviewing existing water rights has not prevailed on the Alameda Creek watershed, otherwise water would have been appropriated to preserve the steelhead run.

Total costs for the proposed restoration effort cannot be assessed precisely due to the many variables affecting costs but have been reported as ranges for each of the elements involved. When considering Alternative 3 - Construct fishway and provide 10 cfs minimum flow over fabridams through May 15, the major costs identified are: 1) constructing the WPRR Weir invert fishway, 2) providing a splash pool at each of the ACWD inflatable dams, 3) installation of 6 fish screens at diversion pipes, 4) annual maintenance and replacement costs, and 5) release of 1,800-3,000 acre-feet of water from an upstream source.

Ranges for these respective costs were reported as:

1) $75,000 - $125,000 (one-time cost) to construct the WPRR Weir fishway.

2) $60,000 (one-time cost) to construct three splash pools.

3) $90,000 - $870,000 (one-time cost) to construct 6 fish screens.

4) $17,000 - $91,000 total annual maintenance and replacement costs.

5) No cost was assigned to the 1,800 - 3,000 acre-feet of water required. However, the San Francisco Water Department is currently in the process of assigning a cost of raw untreated water for nursery usage in the Sunol area located on their property. The project cost will be about $30 per acre-feet (agency staff personal communication). Assuming the fishery water could be purchased at the same price as a SFWD leasee in Sunol (using $30 per acre-foot for release of water from Calaveras Reservoir judged the best source of water to support a fishery), there would be water costs of $54,000 to $114,000 per year. (We reiterate that no cost should be assigned to water release as the public trust doctrine dictates that the public interest should have been considered and water appropriated to prevent destruction of the steelhead run during development of the watershed supplies.)

Based upon the above costs a steelhead fishery could be established for an initial cost of as little as $296,000. Each year thereafter annual maintenance and replacement costs of $17,000 plus water costs of $54,000 for a total

of $71,000 adjusted for inflation. The most expensive estimate that would include a highly-inflated cost of $870,000 for 6 fish screens, would bring the initial year's cost to $1,055,000 for the project. Eighty-three percent of this total is attributed to fish screens! Each year thereafter maintenance and replacement costs of $91,000 per year, plus water costs of $54,000 for a total of $145,000 per year adjusted for inflation.

Although the total production of steelhead measured in terms of projected adult return spawners is unknown, two separate analyses concluded between 300-2,400 fish would be realistic. Assuming initial returns may be at the low end and that the ability of the watershed to produce steelhead will be enhanced by in-stream restoration efforts conducted by sportsmen and other volunteer groups in later years, an average run of at least 1,000 adult steelhead is reasonable. Using 1,000 fish as an average expected return for determining a cost per fish analysis results in the following:

Minimum Cost: Assume 7% Inflation

Adult Return Year	Capital $	Annual M & R $	Annual Water $	Adult Return Spawners	Cost/Fish
1*	296,000	54,650	173,645	300-1,000	$1,747-$524
2	None	58,475	66,175	1,000	$ 125
3	None	62,570	70,806	1,000	$ 133
.					
.					
x					

Maximum Cost: Assume 7% Inflation

Adult Return Year	Capital $	Annual M & R $	Annual Water $	Adult Return Spawners	Cost/Fish
1	1,055,000**	292,550	173,645	300-1,000	$5,070-$1,520
2	None	313,030	185,800	1,000	$ 500
3	None	334,950	198,000	1,000	$ 535
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x					

*No returns expected until the third year after stocking juvenile steelhead.

**Includes $870,000 for installation of 6 fish screens or 83 percent of total.

This analysis reveals that the project cost per fish initially due to the one-time capital costs ranges from $524 per fish to $5,070 per fish, but after the first year of initial adult returns drops dramatically, reflecting the annual costs for maintenance and replacement, plus cost of water. Costs per fish then become more reasonable, ranging from $125-$500 the second year with incremental increases thereafter due to inflation.

The challenge will be to become innovative through use of grant funds, cost sharing, volunteer labor and interagency cooperation to minimize costs. As habitat restoration techniques are implemented to increase pools, spawning areas and create better micro-habitats resulting in larger average annual adult returns, the costs per fish will decrease.

Costs of up to $500 per fish are not outrageous and costs of less than $200 per fish are quite reasonable. Studies conducted in California and Idaho, as well as other states have attached an economic value of hundreds of dollars per fish for salmon and steelhead when considering returns to the economy from sales of fishing and related equipment, plus incidental costs anglers pay to local economies in their pursuit to catch these fish.

Therefore the Alameda Creek steelhead restoration project has been shown to be technically achievable, sufficiently developable (in terms of numbers of fish) and economically justifiable. Alameda Creek is one of few creeks in the Bay Area which can still be restored to support steelhead for the interest and enjoyment of the public. This fishery would supplement the existing put-n-take trout fishery as the 15-30 thousand trout currently stocked annually would either be stocked lower in the watershed at the inflatable dams or within the adjacent Alameda Creek Quarry ponds.

At a time when California's water resources are being allocated for multiple uses statewide, it is imperative that we include sufficient water to preserve, restore and enhance our local natural history. The Alameda Creek steelhead restoration effort provides such an opportunity. The quality of life in such a highly populated urban region as the Bay Area, is positively affected by local government's willingness to support resource diversity and preserve fragments of the local fish and wildlife for generations to come.

B. Recreation Perspective

A self-sustaining population of steelhead once inhabited the Alameda Creek watershed. How many adult fish actually ascended the watershed annually in route to spawning areas is uncertain. However, early accounts of Indian life in Southern Alameda County include harvest of large fish ascending the creeks (probably steelhead and salmon) and "old-timers" who grew up in the area recall occasions when they harvested steelhead from various creeks in the watershed. This resource has been lost along with its recreational opportunity. Development within the watershed has resulted in barriers to upstream migration and habitat losses that have essentially eliminated the species from the watershed. A steelhead restoration effort would reestablish the annual run of adult steelhead enroute to spawning areas and would renew a lost public recreation opportunity.

There would be a great satisfaction from fishermen, environmentalists, fishery biologists, and probably to a segment of the general public of knowing that a steelhead fishery has been restored. There is magic to the term "steelhead" that is exciting to all who have contact either through the sport of fishing or the following of the migration. The concept that a stream, heavily modified by man, has been rehabilitated and again has seasonal water to support a steelhead fishery has become one of the prime goals of the State Department of Fish and Game as well as the many organizations devoted to fishery development.

As was part of history, an anadromous fishery in Alameda Creek would be cyclical. Some years there was more water available; hence, a better migration, better spawning, and combined with a following year runoff into early spring created a larger population for both grill and the returning steelhead for another migration. Until the middle of the 20th century, there were years in which runoff kept Alameda Creek a live stream for many months from all through winter into spring. There were also years at which time there was very little rainfall and in those years the live stream was very short-lived. This same cyclical habitat for a restored stream would be appropriate providing some waters would be released in almost every year with more water being released for a better fishery in the wet years than the dry years. This expectation is true of almost any watershed having an anadromous fishery, and there is no reason that in the very dry years more water could be held and in the wet years more waters released to develop the same cyclical potential for a restored Alameda Creek. Fishermen have always had this cycle and would look forward to the good years and reduce their take on poor years.

One of the great successes in public elections over the past few years has been the overwhelming support of bond issues for public recreation and outdoor environments. All bond issues with the exception of one that had some negative aspects added to it in terms of water conservation for agriculture that turned the voters against the issue. Some eleven bond issues, with the Bay Area being one of the strongest supporters of the development of natural resources for recreation, would indicate the public is vitally interested and would oftentimes pass bond issues in terms of a majority and in the recent election a two-thirds vote to assure the restoration and preservation of our outdoor recreation resources.

Oftentimes, the technical aspects of development, harnessing resources, and special interest groups have caused concern by the overall public on the treatment of our natural resources. To have the technical aspects such as, reservoirs; lumbering too heavily to reduce the water holding capacity of a watershed; the pumping of water for domestic, industrial, and agricultural purposes causing poor water quality or subsidence of land; and the general use of watershed in such a manner that it affects the water quality have met with appreciable opposition and changing of methods of treatment of watersheds. A goal of the restoration of Alameda Creek to make it available for anadromous fishery would be to protect the watershed from additional stream blockage, grading and exposure to erosion, and the reduction of water holding capacity of the watershed to a much cleaner, natural stream bed and practices within the watershed that would enhance its capability of producing water the year-round. The technical issues of uses within the watershed of the water resources and its ability to retain water for year-round use will need to be changed and modified, making the entire environment more desirable for all the uses depending upon Alameda Creek.

Fisheries and the fish have been considered public domain. It has not been the practice nor will it probably ever be the practice in California waters to have the fishery owned by a private source. Stream beds and the water flow within a stream bed for the maintenance of fishery have been considered to be owned by the public. There are locations where the land on both sides of the stream are privately owned and access is not available to the fishermen, but the fish moving up and down the stream and the laws relating to the mainte-

nance of that fishery and the taking of fish for sport or commerce are controlled by the State of California. Alameda Creek has always been a public domain stream even though the water rights and the use of the streams by others for transportation of water has been a right that they have. The fishery has always been open and available to the public, and will probably always remain as such.

Reestablishment of a steelhead run in the Alameda Creek watershed would create a public recreational opportunity for East Bay residents that currently does not exist. Alameda Creek is one of the few streams in the whole Bay Area that can still be revitalized to support steelhead. Development of a steelhead fishery in this urban setting could be a model project for other communities to follow.

C. Water Supply Perspective

The proposed project to establish a steelhead fishery on Alameda Creek was an idea which was worth investigating. However, the findings of the technical report do not support the proposal for several reasons.

1. A steelhead establishment project, even if a dedicated water supply were found, has not been shown to be 1) technically achievable, 2) sufficiently developable (in terms of numbers of fish), or 3) economically justifiable.

The Hanson Report, which was an independent review of K. Burger's analysis of potential fish population size, cautioned that a detailed analysis of the spawning and rearing potential of the watershed had not been performed and that estimating numbers of fish based on data and assumptions extrapolated from other systems may be inaccurate. The Carmel River study may not be transferable to Alameda Creek. K. Burger estimated up to 2,400 steelhead fish could be supported by Alameda Creek under the highest alternative. Hanson's guarded estimate ranged from 100 to 1,000 fish.

There is concern that the 2,400 fish estimate is extremely optimistic. Alameda Creek in its entirely natural state was a borderline steelhead stream located at the southern end of the steelhead territory ranging from Alaska to Central California. Optimum steelhead rivers and streams are in Oregon, Washington and Alaska. Much of the Alameda Creek water supply is blended with imported water from the Delta or from reservoirs and is too warm for steelhead. An extensive tree/shrub planting program is not judged to be a viable solution to the negative temperature effects.

The total initial cost of the steelhead establishment project is estimated to range from $200,000 to $1,000,000. This cost includes fishways, fish screens, and channelization work. This does not include volunteer habitat installation work, maintenance costs, fishway and fish screen replacement costs or the cost of additional water. The value of the water proposed for the project is estimated at $1.2 million per year, if it were available. The unit cost per year for an established steelhead fish ranges from $500 to $12,000 per fish for water costs alone.

Although a cost/benefit analysis has not been performed, by inspection it would be very difficult to economically justify the steelhead establishment project.

2. A steelhead establishment project would negatively affect an existing recreational fishery enjoyed by a broad cross section of the community, and attempt to create a mini-fishery for a special interest group of people.

Currently 20,000 to 30,000 trout are planted each year in the portion of Alameda Creek flowing with water imported by ACWD from the State Water Project. About half the fish are estimated to be caught by people fishing along the creek or channel, and about half are lost to predators (thus supporting other wildlife). The steelhead establishment project would require ending this fishing program because the trout compete with steelhead for the same food. Replacement of the trout program with fishing from the gravel pits/lakes is not judged to be comparable to the stream fishing experience. The preferable alternative would be to expand the trout fishing to include both the gravel pits/lakes and Alameda Creek.

The steelhead establishment project would eliminate or severely limit fishing in Alameda Creek. Proposals such as barbless hook fishing and throwback, limited days/hours for fishing, or lottery tags for fishing would be enforcement nightmares. What was once a pleasant fishing area could become a "fisherman off limits" or patrolled environment reserved for specialists only.

There is no question that the public is supportive of and has approved bond issues for recreation projects and restoration of polluted rivers. This project should not be evaluated based on availability of funding, but on cost-effectiveness and public benefit. This project is not a water cleanup project. This project results in reduced recreation opportunities. Bond issue funds should be better spent on other projects that result in water quality enhancements or significant improvements in recreation to the general public.

3. A steelhead establishment project would negatively affect local water suppliers and consumers by 1) reducing available water for southbay cities, 2) requiring extensive and expensive reconstruction of water facilities, and 3) requiring implementation of less efficient and more costly operational procedures.

The water suppliers potentially affected by the proposed project are the San Francisco Water Department and the State Department of Water Resources (as reservoir operators) and the Alameda County Water District and ACFC&WCD Zone 7 as local water suppliers.

All of the water agencies have shown that their full available supply is needed to serve their consumers in the southbay area. In critically dry years that supply is deficient. ACWD and Zone 7 are faced with potential shortfalls to their State Water entitlements if 1) The State Water Project is not fully developed or 2) the Delta Hearings result in increased water releases for Delta fisheries.

If State Water is used for establishment of an Alameda Creek steelhead fishery then there must be a reduction in water supply available for either local consumers or the delta fishery. If water from SFWD local reservoirs is to be available for a steelhead fishery, then ACWD believes that the water could be

better used locally to 1) make up for any shortfall in State Project water, or 2) provide recharge to keep the groundwater basin above sea level. The water supply situation in California is such that even if recreation money were available to purchase water for this fishery, there is virtually no water to be purchased.

For decades the planning and construction work in Alameda Creek and its watershed has been based on the premise that no viable steelhead fishery exists. The occasional steelhead seen trying to migrate up Alameda Creek is not a native but is lost, confused, or a planted trout "gone wild." Examples of major water supply projects constructed in the Alameda Creek watershed are the San Antonio Reservoir, the Corps of Engineers Alameda Creek Flood Control Channel construction, and the ACWD rubber dams and diversion pipes to the quarry recharge areas.

The ACWD water supply and recharge facilities, which work in harmony with the planted trout fishery, could incur retrofit costs in excess of $900,000 to accommodate establishment of a steelhead fishery. In addition there are costly operation problems.

By having two 1-month delays each year in start of construction of two earthen dikes in Alameda Creek flood control channel, ACWD will loose capability to percolate of about 450 acre-feet of water per year into the groundwater basin.

Fish screens at water diversion intakes will impede flow and reduce the capacity of the intakes. Even if the screens are adequately designed, the diversion flows will need to be constantly monitored and adjusted by ACWD to maintain the CDF&G velocity requirements. Nonmechanical screens will require frequent cleaning manually to prevent clogging from floating trash/debris, filamentous algae and water plants. Mechanical screens with automatic cleaning devices will require security enclosures and routine maintenance.

Maintaining a continuous 10 cfs minimum flow of water over the inflatable dams during smolt emigration will require ACWD to constantly monitor and adjust water flow at other diversion facilities.

ADDITIONAL COMMENTARY: SAN FRANCISCO WATER DEPARTMENT

a) Use of Alameda Creek Waters for Human Consumption

Water development in the Alameda Creek watershed by San Francisco and its predecessor the Spring Valley Water Company ("Spring Valley") has a long history. Spring Valley looked to Alameda Creek in the 1870's to supply the burgeoning population of San Francisco after its supply from reservoirs and coastal streams on the San Francisco Peninsula were exhausted.

Spring Valley first developed the extremely porous supply from the Sunol gravel beds. Calaveras Dam was constructed in the teens and twenties of the 20th century in order to capture the flows of Calaveras Creek, a tributary to Alameda Creek. The original operation of Calaveras Dam released the water for recharge of the gravel beds at Sunol.

The SFWD completed the Alameda Creek diversion dam in 1931. This facility diverts flood flows from Alameda Creek into a tunnel for storage in Calaveras Reservoir.

San Antonio Dam was completed in 1965. The SFWD's storage and diversion dams in Alameda Creek watershed conserve flood flows for human use throughout the year. In addition, San Antonio Dam stores water from the City's Hetch Hetchy Project and water pumped from the Sunol gravel beds via the Sunol pump station.

Historical flow patterns in Alameda Creek were typical of California coast range streams. Flows on the creek were seasonal in nature, with large storm flows occurring during the rainy season from November to April. These flows diminished during the summer; a 1910 report by Samuel Storrow states that the summer flow of Alameda Creek went dry at the mouth of Niles Canyon.

The upper limits of the watershed above SFWD facilities remain largely unaltered by the effects of human development. This ensures high quality drinking water. In contrast to the lack of human impact upstream, major development has taken place downstream. These developments have altered habitat and affect the viability of the stream for purposes of restoring a steelhead fishery. Major alterations include gravel extraction in the Sunol Valley; faberdams used by Alameda County Water District to capture flows for groundwater recharge; the BART invert which provides a major obstacle to fish migration; and the channelization of large portions of the stream bed from the mouth of Niles Canyon to San Francisco Bay.

In the over 100 years of water supply development in the Alameda Creek watershed, no provision for a steelhead fishery has been required. Development decisions have taken place, not only by the major water suppliers but by other entities, which render establishment of a steelhead fishery and consumptive releases of water for fish an extremely expensive proposition. Moreover, the entire economy of the Bay Area has been developed because this water was available, and economic growth continues in reliance upon a continued water supply.

All of the water produced by Calaveras Reservoir has been used to meet the water needs of the SFWD service area since those facilities were purchased by

the City in 1930. Similarly, maximum use is made of San Antonio Reservoir, subject to a license condition prohibiting diversions of more than 19,700 acre feet of stored water during any twelve month period. These facilities have an average yield of approximately 38 million gallons per day ("mgd"). Additional water is delivered from the Hetch Hetchy system to satisfy total service area demands, now totalling nearly 300 mgd to meet the needs of over 2 million users. The SFWD's sources in Alameda County thus satisfy between 10 and 15 percent of the system's current water needs.

Water needs throughout the system's four-county service area will continue to grow well into the next century. The Alameda County Water District and City of Hayward, both served by the SFWD, will exhibit among the highest rates of growth anywhere in the system. Their combined usage in 1986 was 55 mgd and their combined purchases from SFWD in 1985 were almost 30 mgd, or 54.5% of their total supply and 10 percent of all water delivered to the SFWD service area. By the end of this century, their combined need for water will increase by as much as 15 mgd.

While the SFWD's Alameda Creek reservoirs serve other areas, it is significant to visualize the importance of the Alameda Creek reservoir water supply by comparing it to the need for water in that area. Alameda County Water District and Hayward purchases from the SFWD alone nearly equal the average production of the two reservoirs. An additional one-half of that amount will be needed to support the increase in residential, commercial, industrial and community water needs in just the next 15 years.

In time of recurring drought and forecasted shortages of water for human use, the steelhead establishment project would require the SFWD to release 3,000 (alternative 3) to 8,000 (alternative 4) acre feet of water per year. This equals from 7% to 20% of the average long term production of the watershed form 1962 to 1988. These supply figures and demand projections, when coupled with the fact that Calaveras Reservoir has spilled only 13 times in the last 50 years (Table III-A, page 16), indicate that no surplus water is available on a consistent basis to support the proposed fishery project.

b) Additional SFWD Commentary on Proposed Steelhead Fishery

Proponents of the steelhead fishery state that Alameda Creek once supported a "substantial" run of steelhead, yet there is no evidence as to how large the historic fishery was. What is known is that the Alameda Creek fishery was at the southern end of the steelhead range, was subject to reductions in population due to low flows in drought years, and probably did not produce a large commercial harvest. Despite drastic changes in habitat and flow patterns caused by human activity, fishery proponents assume that the mere removal of spawning obstacles and increased flows will establish a steelhead fishery without any facts or comprehensive studies to support this conclusion.

The assumption that a 20 cfs reservoir release would produce 10 cfs to the bay may be erroneous. This assumption does not take into account the extremely porous nature of the Sunol gravel beds in the calculation of percolation losses. The SFWD believes the 10 cfs loss figure to be optimistic. Even assuming the estimate of 10 cfs is correct, of the total amount of water released (8,000 acre feet annually) half of this amount (4,000 af) would not appear in the stream but would be needed to raise the water table in the

gravel beds so that surface flow would exist. This water, lost to subsurface flow, amounts to ten percent of the average annual production of the watershed, and is unreasonable in times of increasing shortages of water.

The San Francisco Water Department recognizes that wildlife and fishery uses are beneficial uses of water under the law. (California Water Code Ss 1243). However, all water use in California is subject to a limitation of reasonable use to prevent waste. (Cal. Water Code Ss 100; Cal. Constitution Article X, Sec. 2) Domestic use of water is given the highest priority. (Water Code 106)

The Department of Fish and Game is not under a legislative mandate to restore steelhead runs in all creeks. By the fishery proponents' own estimates, the creation of a live stream through releases from SFWD dams in the Alameda Creek watershed would require loss of at least 1/2 of the water released in order to produce visible amount of water on the surface of the stream. The large volume of water required, when compared to the small number of fish to be produced, suggests that the use of water for the proposed fishery is an unreasonable and wasteful use of water.

Proponents of the fishery argue that Fish and Game Code Ss 5937 requires the SFWD to release water from its dams. Section 5937 originally applied to dams with fishways. In 1937, it was amended to include dams without fishways. This is after the construction of the SFWD's Calaveras and Alameda diversion dams. These facilities therefore predate the enactment of Ss 5937, which cannot be applied retroactively. While San Antonio Dam was built after 1937, the California Department of Fish and Game withdrew its protest to construction of San Antonio Dam, because the project was seen as having no impact on fish and wildlife. This suggests that Ss 5937 should not be applied to San Antonio Dam.

Proponents of the fishery also cite the "Racanelli decision" (182 Cal. App. 3d 82) and the public trust doctrine in support of creation of the fishery. The Racanelli Decision only applies to the state's reconsiderations of the D-1485 standards imposed in 1978 to protect the waters of San Francisco Bay and the Sacramento-San Joaquin Delta. The Racanelli Decision does not apply to Alameda Creek.

While public trust uses should be considered in any new application to appropriate water, the public trust doctrine has not been applied to vested rights to stored water acquired prior to 1914 and to nonnavigable streams. The public trust doctrine does not apply to man-made reservoirs like Calaveras (Golden Feather Community Assoc. v. Thermalito Irrig. Dist. (1988) 199 Cal.App.3d 402) or to non-navigable streams like Alameda Creek. The seminal case on the public trust doctrine, National Audobon Society v. Superior Court (1983) 33 Cal.3d 419 (the "Mono Lake" case), expressly permits the degradation of some public trust values (i.e. Fisheries) to benefit other uses of water on navigable streams, including domestic and municipal use of water. (Id. at 446.) The history of economic and population growth in California is replete with examples of the appropriation of water for uses unrelated to in-stream public trust values like the proposed steelhead fishery. The value of Alameda Creek water for human use should not be underestimated. The benefits to be gained from the proposed fishery are clearly outweighed by the use of this water for domestic and other human uses.

SF WATER DEPT CITY RESERVOIRS

NAME	Capacity Million Gallons
LAKE MERCED No.	663-207 Gm
SUNSET "	116.0
"	116.0
BALBOA RESERVOIR	18.0
SUTRO "	15.0
"	31.4
SUNSET No. 2	29.5
STANFORD HEIGHTS "	11.0
MERCED MANOR "	3.5
FAIRMOUNT "	7.5
FRANCISCO "	2.5
POTRERO "	1.0
BALBOA PARK "	10.0

SF WATER DEPT STORAGE RESERVOIRS IN BAY AREA

NAME	Capacity Acre Feet	Surface Acres
CALAVERAS	96,820	2,350
CRYSTAL SPRINGS	68,300	2,190
SAN ANDREAS	18,900	1,060
PILARCITOS	3,100	200
SAN ANTONIO	50,940	1,600

ELECTRIC TRANSMISSION LINES

FROM	TO	MILES	STRUCTURE
HOCKSON P/H	NEWARK SUB	19.6	STEEL TOWER
"	NEWARK SUB	19.6	STEEL TOWER
O'SHAUGHNESSY P/H	HETCH HETCHY	14	"
"	HETCH HETCHY	14	"
HETCH HETCHY	MARKHAM SUB	48.4	"
"	MARKHAM SUB	48.4	"
MARKHAM SUB	SUBSTATION A	13.5	"
"	"	"	"

FIGURE III-A

N

LEGEND

Alameda Creek watershed boundary

Area of Alameda County Water District

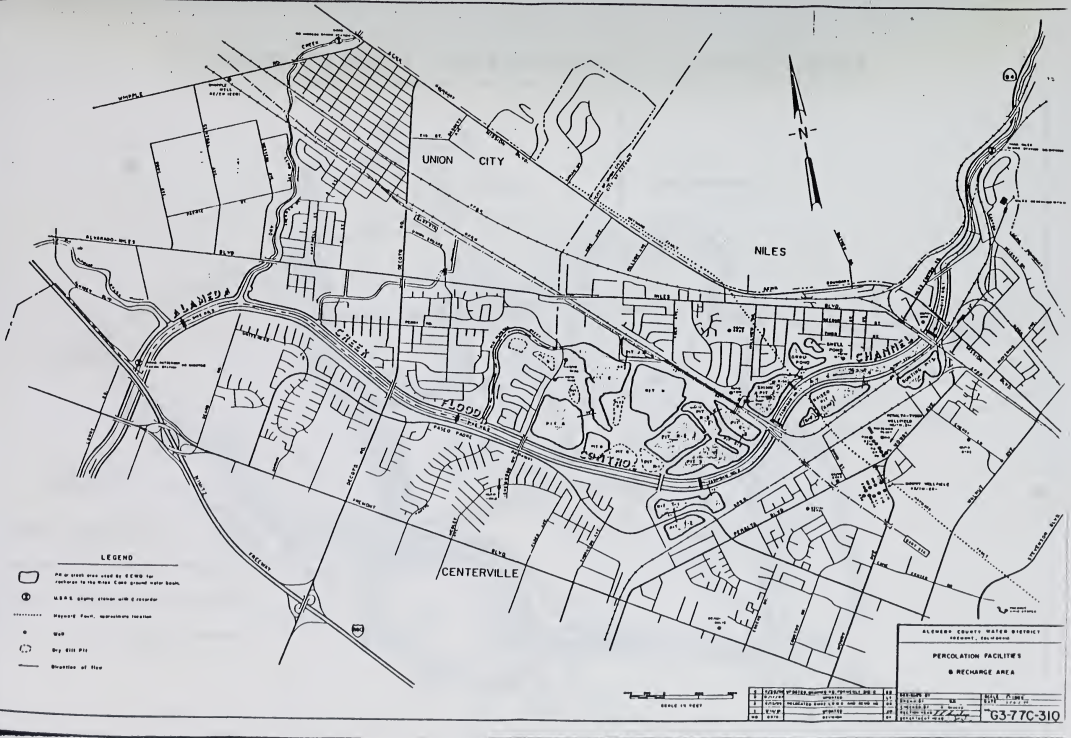
NOTE

Alameda Creek water shed area consists of 633 square miles

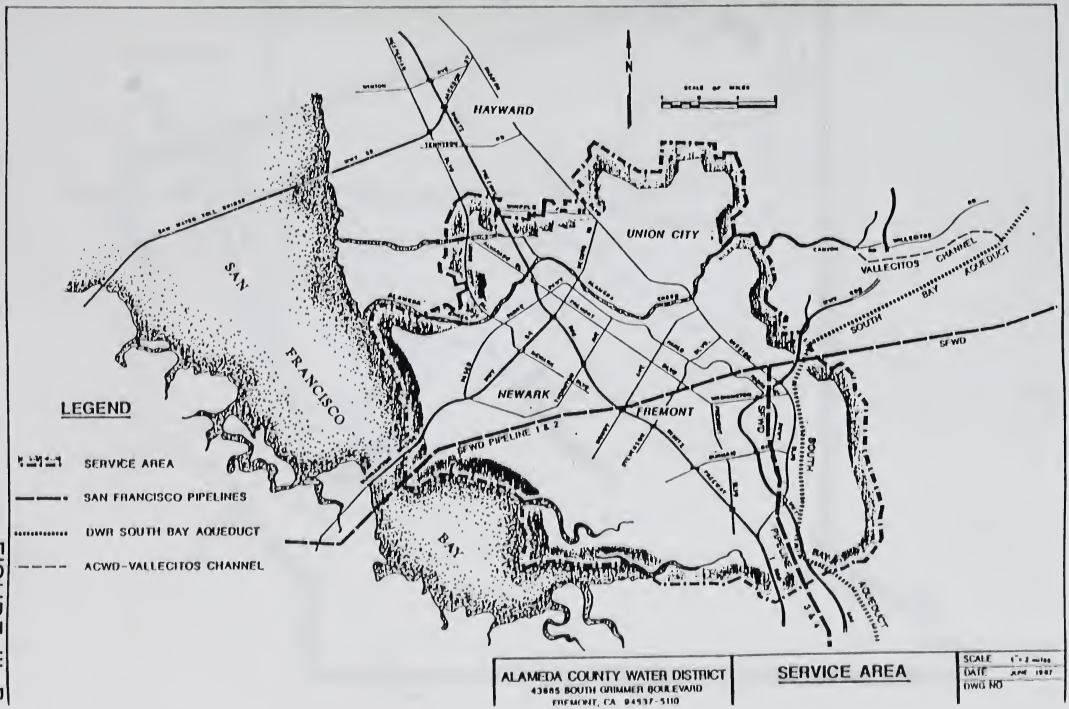
ALAMEDA COUNTY WATER DISTRICT
PLEASANT, CALIFORNIA

ACWD B
ALAMEDA CREEK
WATERSHED

03 77C-22-1


UNION CITY
NILES
CENTERVILLE
ALAMEDA
CREEK
FLOOD
CONTROL
CHANNEL
-N-
LEGEND
ALAMEDA COUNTY WATER DISTRICT
FREMONT, CALIFORNIA
PERCOLATION FACILITIES
RECHARGE AREA
G3-77C-310

ALAMEDA COUNTY WATER DISTRICT SERVICE AREA



LEGEND

- SERVICE AREA
- SAN FRANCISCO PIPELINES
- DWR SOUTH BAY AQUEDUCT
- ACWD-VALLECITOS CHANNEL

FIGURE III-E

ZONE 7 SERVICE AREA

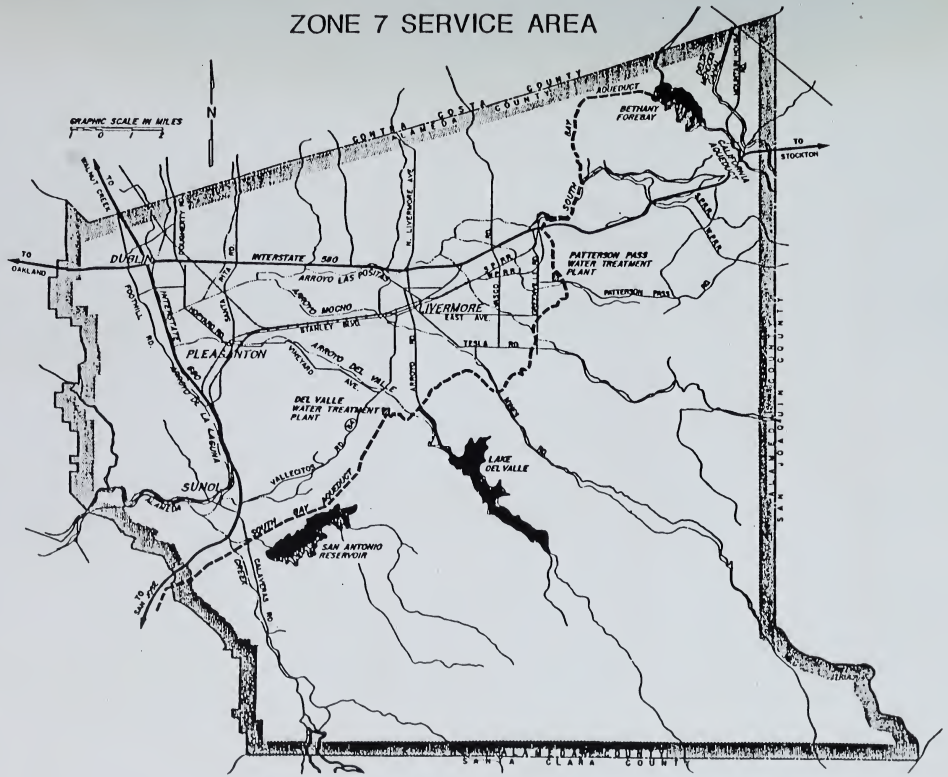


FIGURE III-C

Alameda Creek
Riparian Vegetation Baseline Assessment
Technical Report

Submitted to

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455 Capitol Mall, Suite 230
Sacramento, California 95814

Submitted by

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Project No. 2-1127-1000
February 1993

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ALAMEDA CREEK TECHNICAL REPORT
RIPARIAN VEGETATION BASELINE ASSESSMENT

1.0 INTRODUCTION

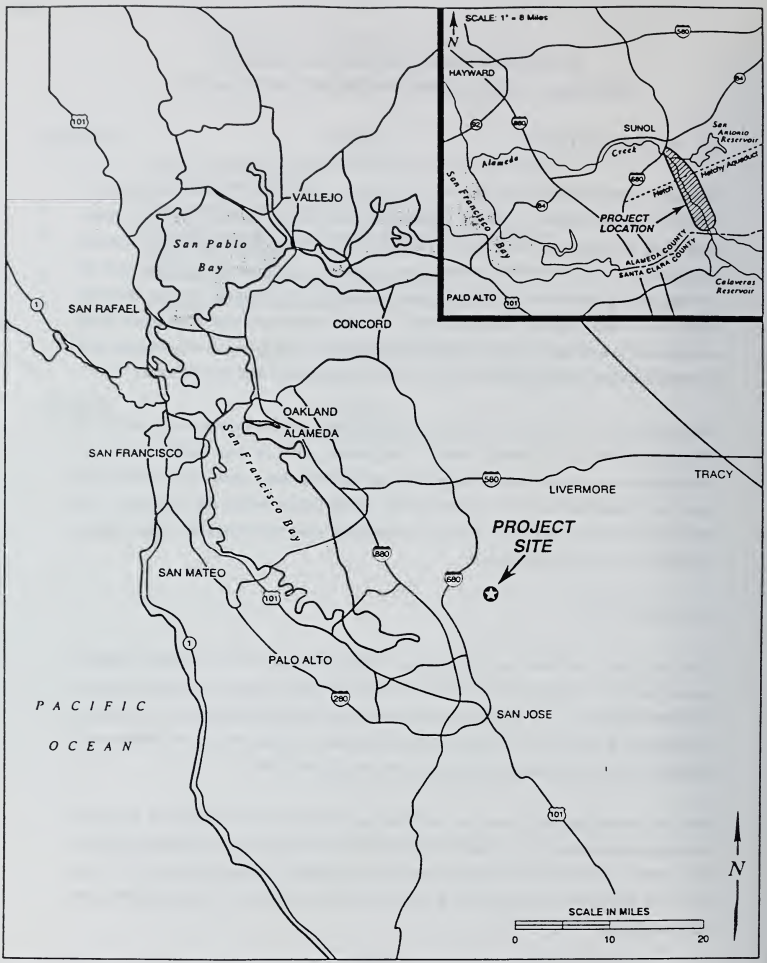
Vegetative cover within the riparian zone of creeks, streams, and rivers is an important component of fish habitat. Riparian vegetation is essential for stabilizing stream banks, controlling silt deposition on the creek bottom, and providing food, shelter and thermal cover for fish. The removal or disturbance of riparian vegetation via activities such as grazing, mining operations, grading, or other mechanical disturbances may significantly reduce the habitat quality of streams for trout. A lack of adequate vegetative cover along and adjacent to a stream or other water course can lead to elevated water temperatures and increased siltation of the streambed, both of which are detrimental to trout fisheries.

This report presents a baseline assessment of the existing riparian vegetation as part of this Watershed Study for Alameda Creek. The primary goals of this assessment are to characterize the existing riparian vegetation and identify those areas that could pose a significant limitation to the reestablishment of a viable fishery within the study area. The purpose of this study was not to provide a statistically valid representation of the riparian vegetation over the entire study area.

2.0 METHODS

The study area included in this riparian vegetation baseline assessment includes approximately 6.5 linear miles of Calaveras and Alameda creeks in Alameda County, California (Figure 1). The study area includes the creek channel beginning at the spillway of Calaveras Reservoir at the upper reach of Calaveras Creek, past its confluence with Alameda Creek, and extends westward to Interstate Highway 680.

Prior to conducting field surveys, the following documents were reviewed to gain a working understanding of the riparian habitats within the study area; the Calaveras Pipeline Replacement Environmental Impact Report (City and County of San Francisco, 1991) and the Final Mitigation and Monitoring Plan for Calaveras Creek, Alameda Creek, and Maguire Springs (EIP, 1992).



OGDEN

Regional Location Map

FIGURE 1

Two separate field surveys were conducted as part of the baseline riparian vegetation assessment. An initial reconnaissance field survey of the study area was conducted by Ogden biologist Michael Wood on August 27, 1992. A second field survey was conducted by Mr. Wood on September 30 through October 2, 1992 during which quantitative vegetation data were collected. Methods employed for each of the field surveys are described below.

Initial Reconnaissance Survey

During the initial reconnaissance survey, the entire 6.5 mile-long study area was surveyed on foot. All readily apparent changes in the vegetation characteristics in the study area were described, photographed, and mapped. Field mapping was conducted using a 1"= 300' topographic map from the Calaveras Pipeline Replacement project and 1"= 400' color aerial photographs (1991).

Based on field observations and aerial photographs, an assessment of the general riparian habitat quality was made. For the purpose of this study, riparian habitat quality is considered a function of the amount of vegetative cover, the dominant species present, and the level of disturbance.

Vegetative cover was assumed to be the primary determinant of habitat quality. The following four preliminary cover categories (henceforth referred to as cover classes) were assigned: 1) 100 percent cover; 2) greater than 50 percent cover; 3) less than 50 percent cover, and 4) bare areas (0 percent cover). Cover classes were visually estimated during this phase; no quantitative data were collected.

Of secondary importance were dominant species and level of disturbance. Dominant canopy species were determined through visual estimates and represented the plant species contributing the most to the vegetative cover within each channel section. Disturbance categories (e.g., high, moderate, low, none) similarly represent visual estimates of the level of impact human activities and land uses have had on the riparian vegetation.

A preliminary map of the vegetation was prepared and used to determine which sections of the creek were to be sampled in detail in the second field survey.

Quantitative Vegetation Survey

A stratified random sampling procedure was used to characterize vegetation within each of the four preliminary cover classes mapped during the initial reconnaissance survey. The entire length of the study area was divided (stratified) into channel sections based on preliminary cover classes identified during the initial reconnaissance survey. Sixteen channel sections thought to best characterize all the cover classes were selected for detailed sampling. The length of each channel section was measured from the field map and one to two random sampling locations were placed in each section. Sampling locations were randomly selected; points (taken from a random numbers table) were placed along a baseline in the selected channel section to identify each sampling location.

At each sampling location, a tape measure was stretched perpendicular to the direction of creek flow, extending from bank to bank at approximately the high water mark. A total of 18 transects were placed in various channel sections as shown in Table 1 and Figures 2A and 2B. In two instances, existing transects placed by the fisheries biologists (T-3, T-5, Reach 1) were utilized.

The collection of quantitative vegetation data was intended to provide input to the fish habitat models being utilized for the project. Vegetative and physical parameters of primary significance to the creek fishery include absolute vegetative cover, canopy overlap above the water surface, canopy height, vegetation offset, percent light obscured, topographic azimuth, and downstream compass bearing. Additional data collected include the location of the creek centerline, creek width, tree diameter at breast height (DBH), and rooting height. Each of these parameters is described below, illustrated in Figure 3, and all the raw field data are provided in Appendix 1.

Vegetative Parameters

Vegetative parameters were collected using the line intercept method. Vegetation parameters measured during the data collection phase include canopy intersect, canopy overhang, canopy height, vegetation offset, percent light obscured, rooting height, and diameter at breast height.

Canopy Intersect: Canopy intersect represents the width of the canopy over the transect line. It is determined by projecting the canopy onto the transect line below. If the canopy

Table 1

LIST OF CHANNEL SECTIONS, COVER CLASSES, SECTION LENGTHS, AND TRANSECTS SAMPLED[1]

Channel Section	Cover Class	Length (feet)	# of Transects Sampled
A	3	600	
B	2	450	
C	3	300	
D	4	750	
E	1	1125	2
F	3	750	
G	4	450	1
H	3	450	1
I	1	600	1
J	2	450	1
K	3	2250	1
L	1	450	1
M	4	150	1
N	2	600	
O	3	975	
P	2	2100	
Q	3	375	
R	3	600	
S	2	900	1
T	3	900	
U	2	1200	
V	3	1200	
W	2	1200	
X	3	450	
Y	4	375	1
Z	3	660	1
AA	1	180	1
BB	3	210	
CC	2	450	1
DD	3	540	
EE	2	510	
FF	3	900	1
GG	4	1575	1
HH	1	775	2
II	4	75	
JJ	1	1050	
KK	3	7800	

1 Refer to Figures 2A and 2B for transect locations.

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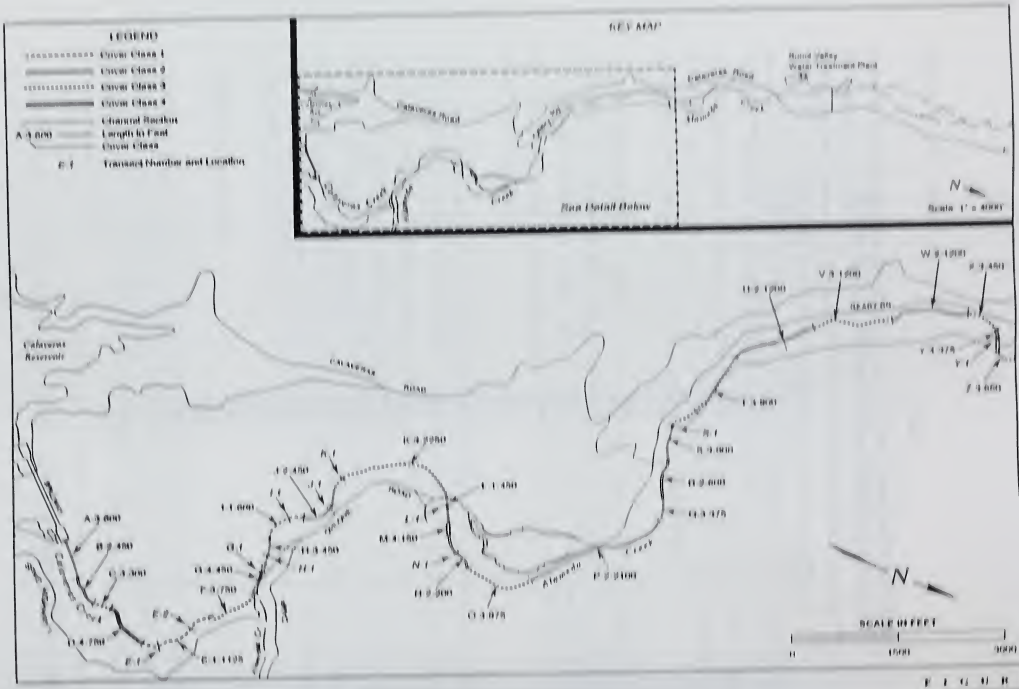
J	2	450	1
K	3	2250	1
L	1	450	1
M	4	150	1
N	2	600	
O	3	975	
P	2	2100	
Q	3	375	
R	3	600	
S	2	900	1
T	3	900	
U	2	1200	
V	3	1200	
W	2	1200	
X	3	450	
Y	4	375	1
Z	3	660	1
AA	1	180	1
BB	3	210	
CC	2	450	1
DD	3	540	
EE	2	510	
FF	3	900	1
GG	4	1575	1
HH	1	775	2
II	4	75	
JJ	1	1050	
KK	3	7800	

1 Refer to Figures 2A and 2B for transect locations.

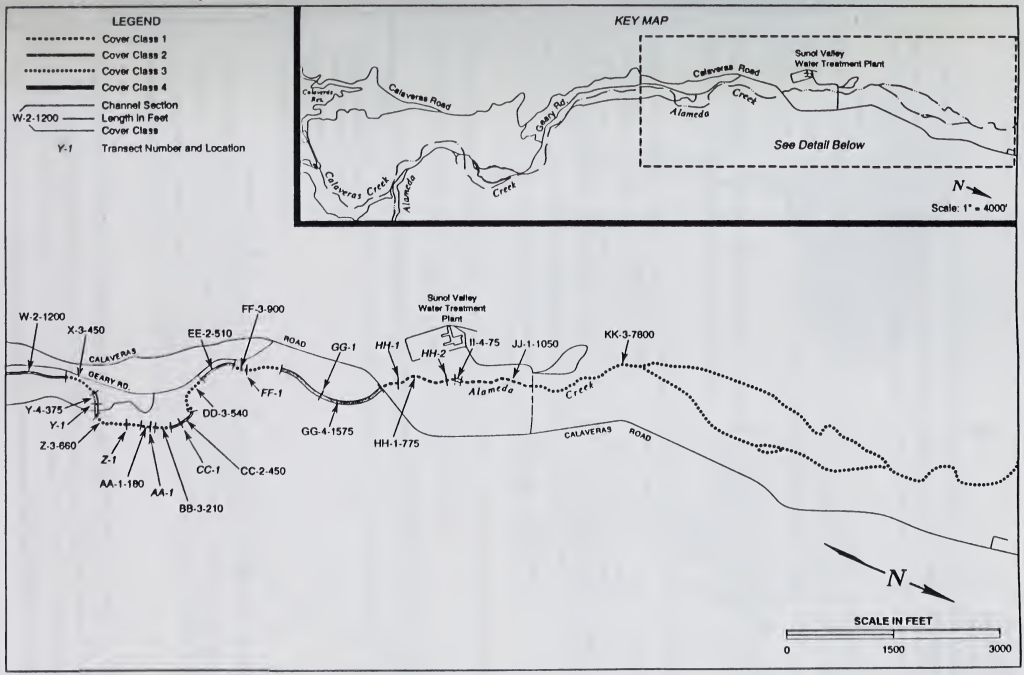


FIGURE

OGDEN

Vegetation Cover Classes Along Calaveras and Alameda Creeks

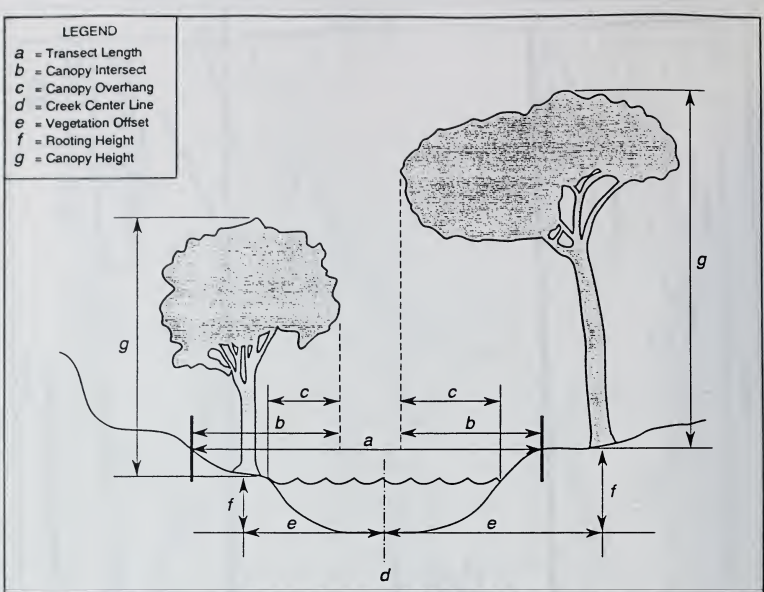
2A



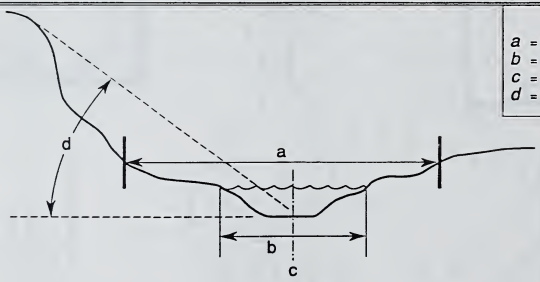
OGDEN

Vegetation Cover Classes Along Alameda Creek

FIGURE 2B



VEGETATION PARAMETERS



PHYSICAL PARAMETERS

OGDEN

Physical and Vegetation Parameter Measurements

FIGURE 3

is composed of different species, the projection of each species is measured. This approach permits the calculation of the relative percent vegetative cover for each species and each canopy stratum, as well as the absolute vegetative cover for the entire transect.

Canopy Overhang: Canopy overhang represents the fraction of the creek's width that is shaded by vegetative canopy by any stratum. It is calculated by dividing total length of the overhanging canopy on either side of the stream by the width of the surface of the water.

Canopy Height: Canopy height is a visual estimate of the average height of each tree or clump of trees whose canopy intersects the transect.

Vegetation Offset: Vegetation offset is defined as the distance each tree or clump of trees is rooted from the centerline of the creek.

Percent Light Obscured: Percent light obscured is a visual estimate of the percent of sunlight blocked by the canopy of each tree or clump of trees intersecting the transect. In essence, it represents an estimate of the density of the foliage for each canopy.

Rooting Height: Rooting height is defined as the elevation above the creek bottom (at its deepest point) that each tree or clump of trees is rooted.

Diameter at Breast Height (DBH): DBH represents the estimated diameter at breast height of all trees with a canopy intersected by the transect; in the case of clumped trees, an average DBH was used.

Physical Parameters

Physical parameters were measured from the creek mid-point. Physical parameters measured during the data collection phase include topographic azimuth, downstream compass bearing, creek centerline, and creek width. These measurements were provided to the fish biologists for their use in the fish habitat models.

Topographic Azimuth: Topographic azimuth indicates the angle, in degrees, above horizontal of the adjacent hills directly in line with each transect. Angle measurements were sighted from the creek centerline using a clinometer. Dense woodland or tall trees adjacent to any transects were ignored; the topographic azimuth was read by looking through the

canopy. Topographic azimuth measurements are intended to provide the fish habitat models with additional information on the degree of shading of the creekbed that would be contributed by the adjacent topography during different seasons of the year.

Downstream Compass Bearing: The downstream compass bearing represents the average direction, in degrees from magnetic north, in which the creek flows. In curved creek sections, a tangential compass reading was taken.

Creek Centerline: The creek centerline is defined as the deepest point in the channel where the greatest volume of water was flowing at the time field work was conducted. This point does not necessarily correspond to the linear center of the creek and can be expected to vary greatly from year to year.

Creek Width: Creek width is the measured width of the surface of the water at the time of the survey. This parameter was subject to change as the amount of water released at the time of the survey was being varied.

3.0 RESULTS AND CONCLUSIONS

After the field data were compared with subjective observations made during the initial reconnaissance survey and aerial photographs, modified cover classes were designated and the vegetation remapped (Figures 2A and 2B). These modified cover classes and vegetation map represent the final and most accurate characterization of the existing riparian vegetation within the study area. Characteristics of each of the modified cover classes are described in detail below.

COVER CLASS 1

Tree overstory consists primarily of dense groves of white alder 20 to 40 feet tall and covering 80 to 100 percent of the creek channel from bank to bank. Overall, the amount of light blocked by the tree canopy is 60 percent or greater and 70 to 100 percent of the surface of the creek is shaded by the tree canopy. Sun flecks through the canopy may be prominent. Channel sections falling into this category tend to be relatively narrow and may border steep, high hillsides and dense woodlands. Additional tree species occurring mostly as scattered individuals but contributing to the canopy include sycamore, big-leaf maple, arroyo willow and red willow. Coast live oak and California bay are frequently present on

the adjacent banks. Emergent wetland vegetation (e.g., cattails) is typically lacking. Shrub understory of nettle, poison oak, and blackberry may also be present on banks and gravel bars. Disturbance is low to none.

Cover Class 2

Canopy of overstory trees and/or saplings cover approximately 60 to 80 percent of the creek channel from bank to bank. The dominant species is white alder around 20 feet tall. Approximately 30 to 60 percent of sunlight is obscured by the tree canopy and 50 to 80 percent of the surface of the water is covered by overhanging tree canopies. Sun flecks on the water surface are less noticeable as more of the water is under open sky. Additional tree species include tall, scattered individuals of sycamore and arroyo willow within the creek channel and coast live oak, big-leaf maple, and madrone on the adjacent banks. Emergent wetland vegetation begins to appear in openings. Mule fat contributes greatly to cover in the creek at the downstream end of the study area. Disturbance ranges from high to low, but is predominantly moderate-low.

Cover Class 3

Vegetation cover consists of low saplings covering 30 to 60 percent of the creek channel. White alder to 20 feet tall is the dominant tree and sapling species. Approximately 35 percent of sunlight is obscured by the tree canopy and tree overhang covers 30 to 70 percent of the surface of the water. Channel sections tend to be broader than cover classes 1 and 2 and exhibit a greater accumulation of alluvium. Scattered mature trees and/or relatively contiguous emergent wetland vegetation may contribute to much of the canopy cover. Co-dominant species include arroyo willow, red willow, big-leaf maple, sycamore, and cottonwood. Coast live oak and California bay laurel may be present on banks. The level of disturbance ranges from high to low, but is predominantly moderate-high.

Cover Class 4

Vegetation in this cover class provides 0 to 30 percent cover within the creek channel. Approximately 20 percent of sunlight is obscured by the tree canopy and tree overhang covers 0 to 30 percent of the water's surface. Channel sections tend to be broad and open; surrounding topography is relatively level. Adjacent upland vegetation tends to be sparse.

Generally, extensive riparian vegetation does not occur within the creek channel. Emergent wetland vegetation may be present in small, isolated patches and scattered trees or saplings of white alder, sycamore, and arroyo willow may be present. The level of disturbance is predominantly high.

Sycamore Alluvial Woodland

Extending from approximately 1,800 feet downstream from the Filter Plant Road bridge to just upstream from the gravel pits is a broad alluvial plain supporting a mature stand of sycamore alluvial woodland. These broad-crowned trees are scattered over the floodplain and are interspersed with infrequent mature willows. Sand and gravel bars may support dense to sparse rows of mule fat. The surface of the creekbed is covered with a thick algal mat.

This entire section of creek was placed into cover class 3, based primarily on the sparse canopy cover throughout most of the section. This stretch of Alameda Creek represents an entirely distinct riparian community compared to other portions of the creek characterized in this report. Any management or restoration plans for this section of the creek should take into consideration the distinct nature of this native riparian plant community.

A summary of all mapped channel sections with their corresponding cover classes and linear length is presented in Table 1. This table also indicates which channel sections were sampled and the number of transects placed in each. Table 2 presents a summary of the total percent canopy cover and total percent canopy overhang for each vegetation transect as determined from the vegetation transects.

A summary of the total linear length of each cover class occurring throughout the study area, the percent of the study area supporting vegetation in each cover class, and the number of transects sampled in each is presented in Table 3. The same information is presented in Table 3A, without the reaches of the creek that support the Sycamore Alluvial Woodland. The number of transects sampled within each cover category are disproportional to the percent of each category actually present throughout the study area. For example, seven transects were placed in cover class 1 which occurs in only 12 percent of the study area and only three transects were sampled in cover class 2 which covers 24 percent of the study area. This disparity is due to the fact that the placement of transects

Table 2

SUMMARY OF COVER DATA
FOR VEGETATION TRANSECTS

Channel Section and Transect No.	Cover Class	Total Percent Vegetative Cover (Transect)	Total Percent Canopy Overhang (Water Surface)
E-1	1	97.0	100.0
E-2	1	83.0	73.7
G-1	4	25.5	15.7
H-1	3	61.2	37.5
I-1	1	86.6	62.1
J-1	2	73.8	84.0
K-1	3	49.4	71.4
L-1	1	86.0	100.0
N-1	2	78.0	77.1
S-1	3	53.9	73.4
Y-1	4	31.5	7.9
Z-1	3	75.5	27.8
AA-1	1	92.6	85.3
CC-1	2	76.4	78.6
FF-1	3	55.2	53.3
GG-1	4	16.7	33.3
HH-1	1	83.3	16.7
HH-2	1	93.3	100.0

Table 3

SUMMARY OF TOTAL AREA SUPPORTING RIPARIAN VEGETATION IN FOUR COVER CLASSES

Cover Class	Length (ft.)	Total Percent of Study Area	Number of Transects Sampled
1	4180	12	7
2	8220	24	3
3	10800	31	5
3*	7800	23	0
4	3375	10	3
Total	34375	100	18

* Sycamore Alluvial Woodland.

Table 3A

SUMMARY OF TOTAL AREA SUPPORTING RIPARIAN VEGETATION IN FOUR COVER CLASSES*

Cover Class	Length (ft.)	Total Percent of Study Area*	Number of Transects Sampled
1	4,180	16	7
2	8,220	31	3
3	10,800	40	5
4	3,375	13	3
Total	26,575	100	18

* Minus the Sycamore Alluvial Woodland.

was based on the cover values estimated for the preliminary cover classes which were modified after the data was collected. Table 4 provides a summary of the average total percent cover, the average total percent canopy overhang over the water surface, and a weighted average of the total percent light obscured by the tree canopy for each cover class.

Because the amount of light reaching the surface of the water is a primary concern in assessing fish habitat, transects were grouped by percent light obscured. For each level of shading, the total intercept length, percent of total transect, and percent creek overhang have been summarized (Table 5). When calculated the percent of each transect or creek width intersected by a given shade category, the greater value was used where two canopies of different values overlapped. Therefore, some of the intercept lengths may appear to differ from the raw data.

4.0 DISCUSSION

Limitations of Analysis

The generalized characteristics of each cover class described above do not represent absolute threshold criteria. A certain amount of subjectivity was required in assigning each channel section to a particular cover class. In some instances, actual data for transects may appear to contradict the cover class in which the transect was placed. For example, channel sections I and HH are both assigned to cover class 1, even though their total percent canopy overhang is substantially below what is considered to be the average range for that category. Such anomalous data are representative of natural patchiness and the random placement of transects, such variation is not surprising. In these cases, the data were overlooked.

Variation in the data is also a result of a small sample size. For this study, a single sample point (or at most, two) was used to characterize an entire channel section. In order to reduce the amount of variation in the data and improve their predictiveness, additional sample points would be required. This would, of course, require a greater level of effort. Because a rigorous study was not warranted in the context of this effort, we have attempted to use quantitative data to assist us in "fine-tuning" our subjective field observations. The disadvantage of such an approach is that we are not able to provide threshold criteria for the parameters measured with a high level of confidence.

Table 4

SUMMARY OF COVER DATA FOR COVER CLASSES

	Cover Class			
	1	2	3	4
Average Total Percent Cover (Transects)*	88.80 (5.5)	76.00 (1.8)	55.00 (4.9)	25.00 (7.4)
Average Total Percent Canopy Overhang (Water Surface)*	77.00 (30.0)	67.00 (26.0)	59.00 (17.0)	19.00 (13.0)
Average Percent Light Obscured (Total Canopy)*	62.00 (14.0)	51.00 (10.0)	35.00 (7.3)	19.00 (7.0)

* Standard deviations given in parentheses.

Table 5

AMOUNT OF LIGHT INTERCEPTED BY TREE CANOPY

Transect #	Transect Length (ft.)	Percent Light Obscured	Intercept Length* (ft.)	Percent of Creek Width
E-1	70.00	0.00	2.00 (2.9)	0.00
		35.00	10.00 (14.3)	0.00
		60.00	35.00 (50.0)	100.00
		80.00	12.00 (17.1)	0.00
		90.00	11.00 (15.7)	0.00
E-2	70.00	0.00	12.00 (17.0)	26.30
		45.00	1.00 (1.0)	0.00
		65.00	24.00 (35.0)	73.70
		85.00	33.00 (47.0)	0.00
G-1	153.00	0.00	114.00 (74.5)	84.30
		25.00	1.00 (0.1)	0.00
		35.00	10.00 (6.5)	15.70
		80.00	8.00 (5.2)	0.00
		100.00	20.00 (13.1)	0.00
H-1	67.00	0.00	26.00 (38.8)	62.50
		40.00	4.00 (6.0)	0.00
		45.00	21.00 (31.3)	37.50
		95.00	16.00 (23.8)	0.00
I-1	82.00	0.00	11.00 (13.4)	37.90
		15.00	1.00 (1.2)	3.50
		70.00	25.00 (30.5)	44.80
		90.00	45.00 (54.9)	13.80
J-1	88.00	0.00	23.00 (26.2)	16.00
		40.00	6.00 (6.8)	24.00
		80.00	1.00 (1.1)	4.00
		80.00	35.00 (39.8)	8.00
		90.00	23.00 (26.1)	48.00

Table 5 (continued)

AMOUNT OF LIGHT INTERCEPTED BY TREE CANOPY

Transect #	Transect Length (ft.)	Percent Light Obscured	Intercept Length* (ft.)	Percent of Creek Width
K-1	77.00	0.00	39.00 (50.6)	28.60
		10.00	1.00 (1.3)	4.80
		40.00	2.00 (2.6)	0.00
		80.00	17.00 (22.1)	38.00
		85.00	18.00 (23.4)	28.60
L-1	86.00	0.00	12.00 (14.0)	0.00
		20.00	4.00 (4.7)	11.10
		30.00	20.00 (23.2)	27.80
		30.00	20.00 (23.2)	61.10
		60.00	11.00 (12.8)	0.00
		70.00	19.00 (22.1)	0.00
N-1	50.00	0.00	11.00 (22.0)	22.90
		20.00	4.00 (98.0)	8.30
		25.00	10.00 (20.0)	20.80
		40.00	9.00 (18.0)	16.70
		65.00	13.00 (26.0)	27.10
		80.00	3.00 (6.0)	4.20
S-1	89.00	0.00	41.00 (46.1)	26.60
		60.00	26.00 (29.2)	36.70
		80.00	12.00 (13.5)	36.70
		90.00	10.00 (11.2)	0.00
Y-1	54.00	0.00	37.00 (68.5)	92.10
		80.00	17.00 (31.5)	7.90
Z-1	53.00	0.00	13.00 (24.5)	72.20
		40.00	9.00 (17.0)	27.80
		80.00	31.00 (58.5)	0.00
AA-1	68.00	0.00	5.00 (7.4)	14.70
		35.00	28.00 (41.2)	29.40
		60.00	10.00 (14.7)	0.00
		60.00	5.00 (7.4)	0.00
		70.00	20.00 (29.4)	55.90

Table 5 (continued)

AMOUNT OF LIGHT INTERCEPTED BY TREE CANOPY

Transect #	Transect Length (ft.)	Percent Light Obscured	Intercept Length* (ft.)	Percent of Creek Width
DD-1	55.00	0.00	13.00 (23.6)	21.40
		70.00	17.00 (31.0)	53.60
		75.00	25.00 (45.4)	25.00
FF-1	67.00	0.00	30.00 (44.8)	46.70
		15.00	4.00 (6.0)	0.00
		35.00	17.00 (25.4)	53.30
		60.00	16.00 (23.9)	0.00
GG-1	108.00	0.00	90.00 (83.3)	66.70
		25.00	7.00 (6.5)	0.00
		90.00	11.00 (10.2)	33.30
HH-1	60.00	0.00	10.00 (16.7)	83.30
		60.00	10.00 (16.7)	0.00
		85.00	15.00 (25.0)	16.70
		90.00	25.00 (41.7)	0.00
HH-2	60.00	20.00	4.00 (6.7)	0.00
		40.00	2.00 (3.3)	0.00
		85.00	27.00 (45.0)	68.20
		90.00	27.00 (45.0)	31.80

* percent of transect length given in parentheses

Conditions of the Existing Vegetation

In general, the riparian vegetation and adjacent upland vegetation along Alameda Creek represents a diverse and relatively intact ecosystem. The three predominant vegetation types present, white alder riparian forest, sycamore alluvial woodland, and Central Coast live oak riparian forest, are all considered plant communities with highest inventory priority (Holland, 1986) and are therefore regarded as representing significant biological resources by the California Department of Fish and Game (CDFG).

The overall quality of the riparian vegetation cover in Alameda Creek is in relatively good condition. Approximately 54 percent of the study area fits into cover class 3, 24 percent fits into cover class 2, and 12 percent fits into cover class 1. If the sycamore alluvial woodland is omitted from the study area, the percent area covered by cover classes 3, 2, and 1 changes to 41, 31, and 16, respectively. Again, omitting the sycamore alluvial woodland, this means that 88 percent of the creek supports riparian vegetation with an absolute cover exceeding 30 percent and 47 percent has vegetative cover exceeding 70 percent.

Although vegetative cover and the level of disturbance vary over the length of the study area, the existing riparian vegetation is fairly contiguous and does not exhibit signs of being senescent. In fact, the presence of dense stands of white alder saplings indicates that the vegetation is successional and that it is reestablishing in previously sparsely vegetated sections of the creek. Even after six years of drought conditions, the riparian vegetation on Alameda Creek appears to be self-sustaining.

Disturbances to Habitat Quality

With the exception of the gravel quarries at the downstream end of the study area which have virtually eliminated all of the original creek habitat, the primary source of impact to the riparian vegetation appears to result from cattle grazing and trampling. Cattle browse the herbaceous plants and tree saplings which initiate the revegetation of open portions of the creek. They also trample the vegetation and creek banks causing erosion and siltation.

The greatest level of disturbance attributable to cattle activity appears to be from the western property boundary of the Sunol Regional Park downstream to the Rosedale Bridge. Cattle

activity in some areas has severely reduced vegetative cover and has greatly disturbed the creek banks and bottom.

Within the Sunol Regional Park, human disturbance takes the form of off-trail hiking and trampling of vegetation along creek banks. However, the impact of such human activities on the riparian vegetation appears to be minimal.

Downstream from the Sunol Valley Water Treatment Plant and throughout the sycamore alluvial woodland, thick algal mats are prevalent in the entire creek channel.

Potential for Habitat Restoration

There is a high potential for restoring some of the more disturbed portions of the creek and a high chance for the success of restoration efforts. Because native vegetation is well-established throughout the creek, there also exists the likelihood that natural revegetation would result if cattle are excluded. This is especially true where short stretches of bare creek are bordered by existing stands of riparian vegetation. Restoration of longer stretches of unvegetated creek could be expedited through plantings.

APPENDIX 1
RAW FIELD DATA

Appendix 1

RAW FIELD DATA COLLECTED FROM EACH TRANSECT

Transect #	Species	Intercept Length (ft.)	Height (ft.)	Veg Offset (ft.)	Percent Obscured	DBH (in.)	Root Ht. (in.)	Creek Centerlin (ft.)
E-1	Plarac	0-10	45	44	35	22	36	
	open	10-12						
	Sallae	12-49	35	29	60	24	24	
	Alnrho	18-23	6	18	20	1	0	
	water	35-47						41
	Alnrho	47-61	20	10	80	18	12	
	Acemac	59-70	25	23	90	14	36	
	notes: N azimuth = 30, S azimuth = 36; compass bearing = 335 located at 168' downstream from pipe tunnel photos 1 and 2							
E-2	Plarac	0-8	60	26	45	22	60	
	Alnrho	1-25	20	9	65	6	16	
	Sallas	5-9	6	9	20	1	16	
	Carex	0-5.5			75			
	water	9-31						20
	open	25-37						
	Umbcal	37-70	60	50	85	24	84	
	notes: N azimuth = 37, S azimuth = 28; compass bearing = 280 located 300' downstream from pipe tunnel photos 3 and 4							
G-1	Acemac	0-8	40	90	80	18	120	
	open	8-54						
	Typlat	54-55	3	36	25		8	
	open	55-110						
	water	59-123						94
	Typlat	110-120	6	30	35		6	
	open	120-133						
	Umbcal	133-153	50	73	100	14	48	
	notes: N azimuth = 25, S azimuth = 36; compass bearing = 270 located 360' downstream from confluence photos 5 and 6							

Appendix 1 (continued)

RAW FIELD DATA COLLECTED FROM EACH TRANSECT

Transect #	Species	Intercept Length (ft.)	Height (ft.)	Veg Offset (ft.)	Percent Obscured	DBH (in.)	Root Ht. (in.)	Creek Centerlin (ft.)
H-1	Plarac	0-4	30	61	40	12	48	
	open	4-20						
	Alnrho	20-36	20	18	95	6	24	
	Alnrho	27-36	10	15	45	1	24	
	water	36-52						46
	open	36-46						
	Alnrho	46-67	45	21	45	18	60	
	Bacpil	48-50	2		40			
	Carex	50-52			80			
	Carex	56-57			80			
	notes: N azimuth = 18, S azimuth = 35; compass bearing = 260 located 30' upstream from T-2 (Reach 1) photos 7 and 8							
I-1	Alnrho	0-25	30	14	70	6	30	
	water	12-41						24
	open	25-34						
	Typlat	34-35	6		15			
	open	35-37						
	Alnrho	37-82	15	20	90	5	24	
	notes: N azimuth = 15, S azimuth = 48; compass bearing = 320 located at T-3 (Reach 1) photos 9 and 10							
J-1	Alnrho	0-23	30	24	90	5	42	
	water	11-36						24
	Sallas	15-24	10	15	80	4	24	
	open	24-28						
	Alnrho	28-37	15	16	40	6	24	
	Alnrho	34-69	30	28	80	10	36	
	open	69-88						
	notes: N azimuth = 29, S azimuth = 22; compass bearing = 290 located at T-5 (Reach 1) photos 11 and 12							

Appendix 1 (continued)

RAW FIELD DATA COLLECTED FROM EACH TRANSECT

Transect #	Species	Intercept Length (ft.)	Height (ft.)	Veg Offset (ft.)	Percent Obscured	DBH (in.)	Root Ht. (in.)	Creek Centerlin (ft.)
K-1	Alnrho	0-18	30	16	85	8	36	
	Sallas	9-15	8	6	25	2	24	
	water	12-20						16
	Typlat	18-19	5	2	10		0	
	open	19-26						
	Sallas	26-30	8	16	40	2	12	
	Alnrho	28-45	20	8	80	10	12	
	water	37-50						43
	open	45-77						
	notes: N azimuth = 12, S azimuth = 29; compass bearing = 300 located 51' upstream from T-7 (Reach 1) photos 13 and 14							
L-1	Alnrho	0-20	40	11	30	16	18	
	Sallas	0-10	40	21	30	15	24	
	Carex	7-9			80			
	water	8-44						18
	Alnrho	18-40	25	11	30	3	0	
	Carex	24-27			80			
	Carex	29-30			80			
	Alnrho	36-44	7	19	20	1	0	
	open	44-48						
	Alnrho	48-67	25	32	70	4	18	
	open	67-75						
	Plarac	75-86	50	82	60	24	36	
	notes: N azimuth = 11, S azimuth = 18; compass bearing = 70 located 71' downstream from Timber Bridge photos 15 and 16							
N-1	Sallas	0-3	25	33	80	3	18	
	Plarac	0-3	40	45	80	18	30	
	Alnrho	0-16	20	34	65	8	12	
	water	1-49						35
	Carex	13-15			80			

Appendix 1 (continued)

RAW FIELD DATA COLLECTED FROM EACH TRANSECT

Transect #	Species	Intercept Length (ft.)	Height (ft.)	Veg Offset (ft.)	Percent Obscured	DBH (in.)	Root Ht. (in.)	Creek Centerlin (ft.)
N-1	Sallas	16-20	6	17	20	1	0	
(contin)	Typlat	20-30	8	25	25			
	open	30-41						
	Alnrho	41-50	20	14	40	6	10	
	notes: N azimuth = 18, S azimuth = 15; compass bearing = 30 located 340' downstream from from trestle crossing #2 photos 17 and 18							
S-1	Queagr	0-10	30	79	90	14	36	
	open	10-43						
	Alnrho	43-69	20	15	60	4	12	
	water	58-88						71
	open	69-77						
	Alnrho	77-89	20	12	80	8	12	
	notes: N azimuth = 20, S azimuth = 48; compass bearing = 280 located 324' downstream from from trestle crossing #3 photos 20 and 21							
Y-1	open	0-37						
	water	2-40						18
	Alnrho	37-54	25	28	80	6	16	
	notes: N azimuth = 18, S azimuth = 16; compass bearing = 70 located 60' downstream from from trestle crossing #4 photos 22 and 23							
Z-1	Alnrho	0-9	20	9	40	6	18	
	water	4-22						12
	open	9-22						
	Alnrho	22-53	25	17	80	6	18	
	notes: N azimuth = 30, S azimuth = 20; compass bearing = 350 located 270' downstream from from dirt road crossing photos 24 and 25							

Appendix 1 (continued)

RAW FIELD DATA COLLECTED FROM EACH TRANSECT

Transect #	Species	Intercept Length (ft.)	Height (ft.)	Veg Offset (ft.)	Percent Obscured	DBH (in.)	Root Ht. (in.)	Creek Centerlin (ft.)
AA-1	Alnrho	0-20	55	18	70	24	18	
	water	1-35						18
	open	20-25						
	Plarac	25-68	65	53	35	30	24	
	Alnrho	40-48	10	25	10	1	10	
	Acemac	53-68	25	60	60	14	30	
	Umbcal	52-63	70	60	60	30	36	
	notes: N azimuth = 36, S azimuth = 17; compass bearing = 350 located 570' downstream from from dirt road crossing photos 26 and 27							
DD-1	open	0-7						
	Alnrho	7-32	25	23	75	4	10	
	water	25-53						38
	open	32-38						
	Alnrho	38-55	50	15	70	18	16	
	Alnrho	41-55	25	15	70	7	16	
	notes: N azimuth = 39, S azimuth = 19; compass bearing = 320 located 120' upstream from bend in creek photos 28 and 29							
FF-1	Plarac	0-6	45	35	15	24	30	
	Alnrho	4-21	20	9	35	4	8	
	water	13-28						20
	open	21-51						
	water	49-66						59
	Queagr	51-67	70	21	60	32	72	
	Alnrho	58-67	15	8	20	3	12	
	notes: N azimuth = 17, S azimuth = 22; compass bearing = 340 located 2475' upstream from Rosedale Bridge photos 31 and 32							

Appendix 1 (continued)

RAW FIELD DATA COLLECTED FROM EACH TRANSECT

Transect #	Species	Intercept Length (ft.)	Height (ft.)	Veg Offset (ft.)	Percent Obscured	DBH (in.)	Root Ht. (in.)	Creek Centerline (ft.)
GG-1	Sallas	0-11	35	103	90	24	60	
	open	11-101						
	water	89-107						101
	Alnrho	101-108	15	8	25	4	24	
	notes: N azimuth = 28, S azimuth = 10; compass bearing = 355 located 600' upstream from Rosedale Bridge photos 33 and 34							
HH-1	Plarac	0-15	80	27	85	36	30	
	Alnrho	0-7	20	19	50	2	8	
	Sallas	0-9	20	19	55	4	8	
	Alnrho	4-10	6	11	40	1	2	
	open	15-25						
	water	13-25						19
	Urthol	25-35	4	6	60			
	Alnrho	35-60	70	41	90	18	48	
	Alnrho	35-48	8	21	90	2	16	
	Sallas	52-60	70	51	90	12	48	
	notes: N azimuth = 12, S azimuth = 20; compass bearing = 330 located 360' downstream from Rosedale Bridge photo 35							
HH-2	Ruburs	0-5			70			
	Alnrho	0-27	65	18	85	18	36	
	water	4-19						13
	Alnrho	16-22	8	7	25	1	6	
	Alnrho	15-29	20	8	40	3	8	
	herbs	20-43	2	7	20			
	water	43-50						47
	Alnrho	33-60	65	7	90	16	12	
	notes: N azimuth = 18, S azimuth = 22; compass bearing = 320 located 280' upstream from creek crossing #5 photo 36							

Appendix 1 (continued)

RAW FIELD DATA COLLECTED FROM EACH TRANSECT

Species codes:

Acemac = Acer macrophyllum (big-leaf maple)
Alnrho = Alnus rhombifolia (white alder)
Bacpil = Baccharis pilularis (coyote brush)
Carex = Carex sp. (sedge)
Plarac = Platanus racemosa (Sycamore)
Queagr = Quercus agrifolia (coast live oak)
Ruburs = Rubus ursinus (California blackberry)
Sallae = Salix laevigata (red willow)
Sallas = Salix lasiolepis (arroyo willow)
Typlat = Typha latifolia (broad-leaved cattail)
Umbcal = Umbellularia californica (California bay)
Urthol = Urtica holosericea (Nettle)

APPENDIX D

ALAMEDA CREEK
REVEGETATION/RESTORATION REPORT
FEBRUARY 1993

Alameda Creek Revegetation/Restoration Report

Prepared for
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For Submittal to:
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Water Supply Division
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May 1993
Project No. 211271000

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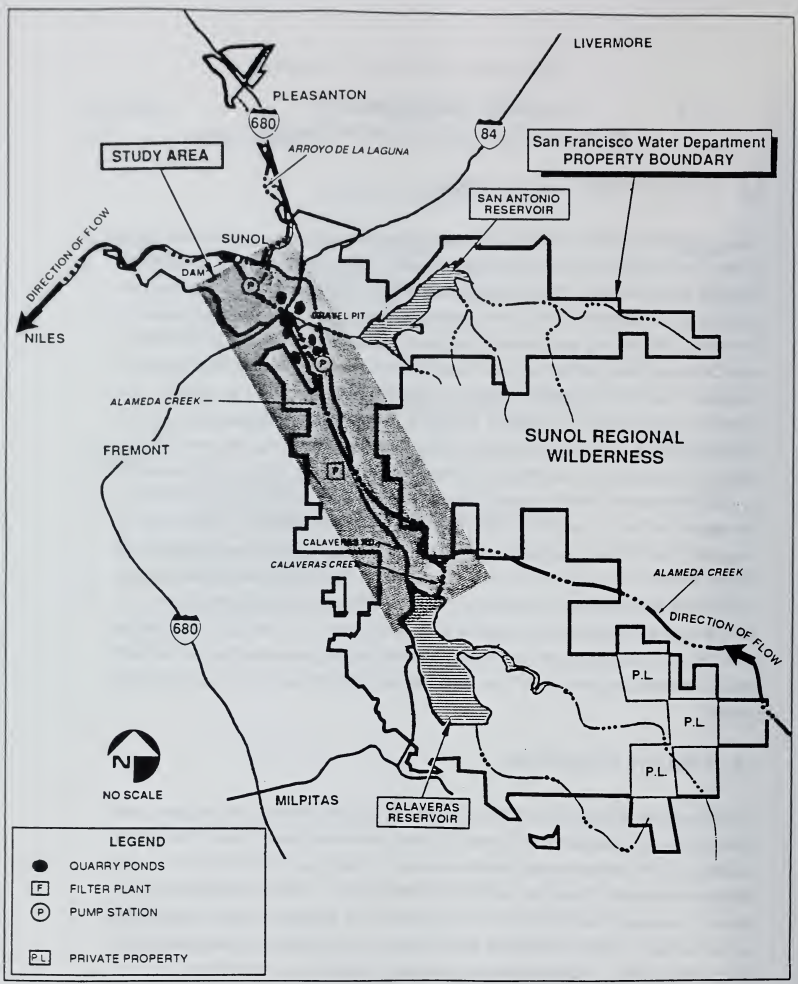
ALAMEDA CREEK RIPARIAN REVEGETATION/RESTORATION REPORT

1.0 INTRODUCTION and PURPOSE

Alameda Creek lies within San Francisco Water District watershed management lands east of the City of Fremont, California along the western and southern borders of the Sunol Regional Wilderness Park. The creek originates in the southern part of this wilderness area (See Figure 1). Calaveras Creek joins Alameda Creek directly to the north of Calaveras Reservoir. The primary study area of this report is Alameda Creek from its confluence with Calaveras Creek to Highway 680. Some discussion is also given to a short portion of Alameda Creek west of Highway 680 to its junction with Arroyo de la Laguna. The purpose of this report is to make a feasibility study of the revegetation/restoration possibilities along Alameda Creek which would accommodate the reestablishment of a trout fishery in the stream channel through the study area. A secondary purpose of this report is to assess the potential costs for general riparian revegetation of portions of the creek which are now, or will be in the future, disturbed by gravel mining operations. This report is prepared by the Habitat Restoration and Management Group of Ogden Environmental and Energy Services Co. (Ogden). It is part of a series of studies that are presently being done to determine the feasibility of establishing a trout fishery potential within the study area. As such, this report integrates the findings of these other reports. In particular, the fisheries work done by Biosystems Analysis (BA) and the hydrological research done by Luhdorff and Scalmanini Engineers (LSE) has been utilized to divide the study area into three reaches.

2.0 PRESENT CONDITIONS

Current and past management practices have had a substantial effect on the vegetation and fishery along the Alameda Creek stream channel in the study area. One of the largest influences on the stream ecology was the damming of Calaveras Creek (which is the main tributary to Alameda Creek) at the Calaveras Reservoir site. This dam reduced the peak flows in Alameda Creek during the January-February maximum runoff period from perhaps as high as 120 cubic feet per second (cfs) to a current flow of somewhere nearer 20 cfs (Hagar 1993). Reduced flows have adversely affected the stream fishery.



OGDEN

Study Area Location

FIGURE 1

A second major factor affecting the creek has been the use of the watershed lands in the upper two-thirds of the study area for grazing. Cattle grazing has denuded many areas of vegetation cover along the creek (Ogden 1992) causing increased siltation detrimental to trout spawning and also resulting in higher water temperatures due to lack of vegetation cover.

A third major factor affecting stream ecology in the study area has been sand and gravel mining in the lower portions directly to the south of Highway 680. This activity has left the lower portion of the watershed in a highly disturbed state with very little if any riparian vegetation cover. The mining has also left a number of open water ponds in this area. However, riparian cover may have historically been minimal in this area since summer flows appears to have been insufficient to keep the water table near the surface through the summer (Erlewine 1993).

Two other land uses occur along the creek. These are the leasing of minor portions of land along the eastern lower border of the creek to nursery operations and the construction of a water treatment plant at the middle of the study section where Calaveras Road crosses the creek. However, these land uses appear to have little actual impact on the creek ecology.

Figures 2 and 3 document these current land uses within the study area. Based on the management practices associated with these land uses, the study area can be divided into three different creek reaches. These sections run from the southern boundary of the study area to the water treatment plant, from the water treatment plant to the Hetch Hetchy Aqueduct crossing, and from the Aqueduct crossing to Highway 680. Each of these sections are examined in greater detail in Section 2.1 below. For the purposes of this study these sections will be called reaches 1, 2, and 3 running from south to north (see Figures 2 and 3).

2.1 Reach 1: Calaveras Dam to the Treatment Plant

The majority of this reach of the creek is under lease to the East Bay Municipal Park District (EBMPD). The creek channel in this reach is dominated by riparian woodland vegetation with bordering oak woodlands on its outer edges (see Ogden 1992 for greater detail). There are three grazing areas which EBMPD controls. Two of these subleases are on the western border of Alameda Creek while one borders the Sunol Regional Wilderness on the east. Only the two leases on the western side of the creek channel are presently subleased

for grazing. The watershed area to the east of the creek channel bordering the Sunol Wilderness is managed by EBMPD as part of the wilderness area. However, there are presently no barriers preventing cattle grazing on the lease areas west of the creek from crossing the creek and entering onto the wilderness areas to the east.

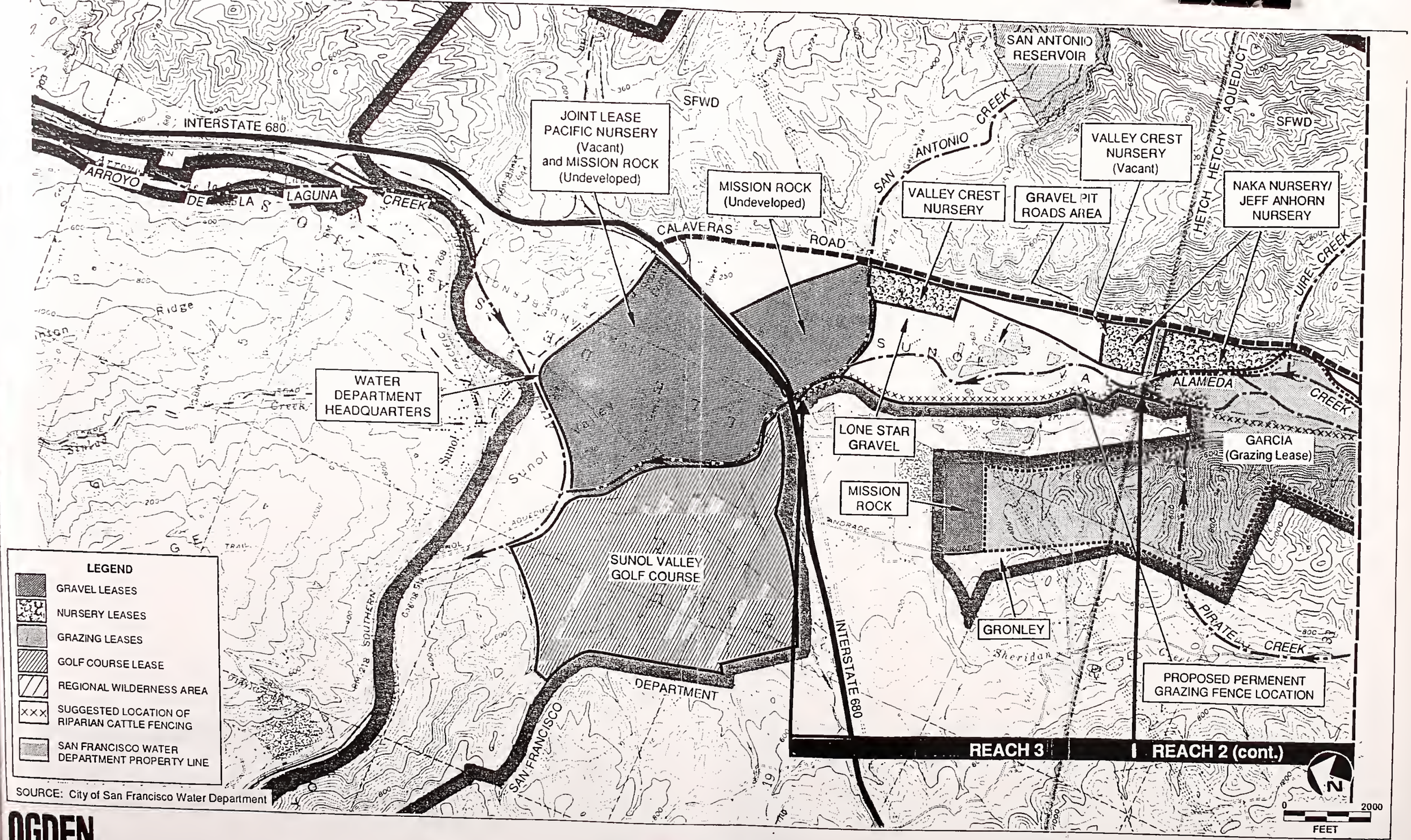
The final lease parcel within this reach is Lease G which is another grazing lease extending northward from Calaveras Creek to Alameda Creek and just south of Leyden Creek on the western side of the watershed. A short section of Alameda Creek also passes through the Sunol Wilderness where EBMPD manages the area adjacent to the creek as a day use and campground area.

Although use of the campground area has resulted in only minor and localized disturbance to riparian vegetation along Alameda Creek, the grazing practices on the western side of the creek have created continuing degradation of riparian vegetation in all areas of this reach where cattle can reach the creek edges. As a result most areas of riparian vegetation found through this reach show either less than 50 percent canopy cover or disturbance (Ogden 1992).

The primary factors affecting the creek ecology in this reach are therefore grazing and the historic reduction in the water supply due to Calaveras Dam. Reduction in the water supply has resulted in insufficient flow to keep water temperatures within an acceptable range for trout in many parts of this reach. Slower flow rates have also created stagnant pools which accumulate sediments and are then overgrown by cattail (*Typha* sp.) colonies. These cattail colonies have gradually covered gravel beds and pool areas within the creek. Low flows combined with higher water temperatures have also created algal blooms in the pools which cover pool surfaces by early summer with dense mats of algae growth. Grazing along the creek has denuded banks in many areas and degraded stream bank profiles. The loss of vegetation has allowed more sunlight to reach the water surface thus also contributing to higher water temperatures.

2.2 Reach 2: Water Treatment Plant to Hetch Hetchy Aqueduct Crossing

This western border of the creek and flood plain in this reach is leased almost entirely to one lessee, Garcia, for cattle grazing. The eastern border of the flood plain, is leased to nursery use. The creek enters a floodplain aquifer in this reach where surface water

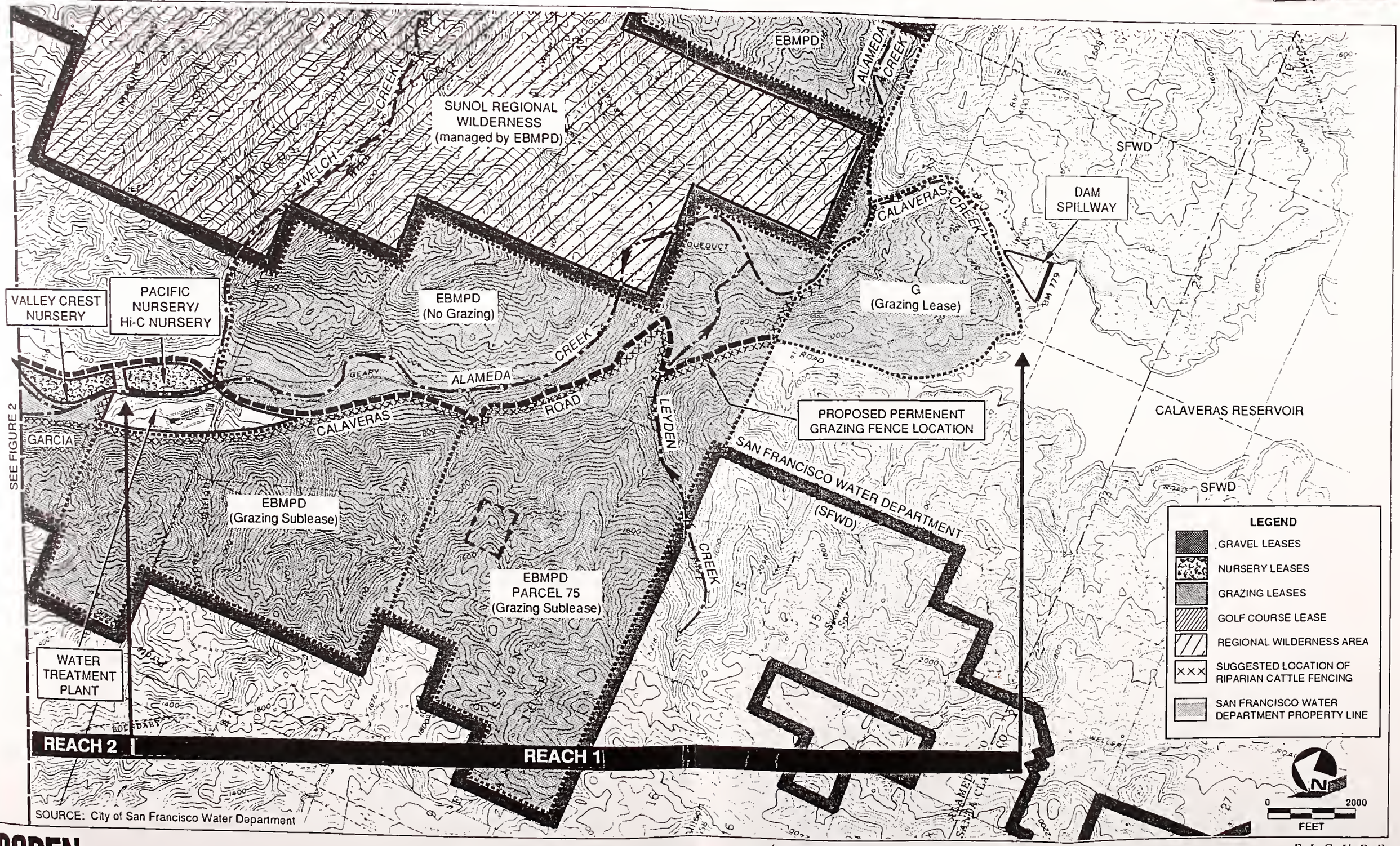


SOURCE: City of San Francisco Water Department

OGDEN

Northern Half of Study Area

FIGURE 2



SOURCE: City of San Francisco Water Department

OGDEN

Southern Half of Study Area

FIGURE 3

infiltrates and drops below the ground surface during the summer months. This water table drop may have been further accentuated by the drop in surface elevations caused by gravel mining in the Reach 3 area. However, it is believed the historic water table remained at the surface through the summer months only in the upper end of this reach (Scalmanini 1993). This hydrologic regime has produced a different vegetation cover from that found in the upper reach of the creek dominated by a few large sycamores (*Platanus racemosa*) and a more xeric mulefat scrub (*Baccharis glutinosa*) (see Ogden 1992).

2.3 Reach 3: Hetch Hetchy Aqueduct Crossing to Highway 680 and on to Arroyo de la Laguna

The third reach of the creek, from the Hetch Hetchy Aqueduct crossing to Highway 680 was historically probably very similar in both vegetation cover and trout habitat value to Reach 2; however, the majority of this area south of Highway 680 has been extensively mined for sand and gravel over at least the last 20 years by Lonestar and Mission Rock. Section 2, on the other hand, was not mined because insufficient sand and gravel deposits appear to exist in this area to warrant such development (Hutchinson 1993). Reach 3 is also characterized by a broad floodplain; however, the alluvium is generally deeper here than in Reach 2 (approximately 40 feet) and underneath this alluvium is a relatively deep, low permeability soil layer (Livermore Gravels) from which gravel mining has taken place (Hutchinson 1993). Historically this reach of the creek appears to have recharged the large underground aquifer which would fill from the impermeable gravel layer to the surface during the winter months and then slowly recede belowground in the summer. It is not believed that the historic water table remained at the surface during the summer (Scalmanini 1993). Gravel mining has removed substantial portions of the alluvium which has decreased belowground storage in the aquifer. It is estimated that the original storage capacity of the highly permeable upper (<40' deep) aquifer was approximately 5,600 acre-feet and that perhaps only 2,800 acre-feet of subsurface water storage capacity remains today (Hutchinson 1993). However, the pits left after gravel mining have probably added 20,000 acre-ft. of aboveground storage capacity to the area of which about half is presently filled. The water table has now dropped 20 feet below the surface year around apparently due to the draw down effects of the gravel pit lakes. Thus at present, there does not appear to be any surface flow except for short periods during high-volume winter storm events in this reach. During summer months, the only surface water still evident is in the deep pit lakes left after gravel excavation is completed which fill briefly during the winter months but then quickly drop after the winter rains to approximately 20 feet below the

surface. There is no present trout habitat value in this reach and historically this part of the channel probably only served as a migration route for the fish (Hagar 1993).

Besides the sand and gravel operations south of Highway 680 there are also a number of nursery leases along the eastern edge of the flood plain. However, their management practices do not appear to have had a significant effect on the creek ecology (see Section 4.0).

The final section of this final creek reach extends from Highway 680 north to the junction of Arroyo de la Laguna. It is bordered on the west by the Sunol Golf Course leased from the SFWD. Native vegetation cover has been removed from most golf course areas but because of steep topography along the western bank of Alameda Creek, a band of fairly high quality riparian woodland remains. On the east is a large flat parcel of land on which a water storage reservoir (water temple) and the local SFWP headquarters are located. The majority of this land is currently leased by both Pacific Nursery and Mission Rock; however, neither is utilizing the site at present for either nursery or gravel operations. All native cover has been removed from the lease lands except for a fairly good quality band of riparian woodland which remains along the creek edge. Mission Rock has submitted an application to the County to mine this area for gravel. Trout habitat value in this reach is low because little water remains in the channel over the summer months. Habitat value can be expected to decrease further when gravel mining begins because of the expected lowering of the water table (although this will be partially mitigated by required subsurface cutoff walls between the creek and the new gravel pits) and potential disturbance of creekside vegetation on the east bank.

3.0 RESTORATION/REVEGETATION ANALYSIS AND RECOMMENDATIONS

The purpose of this section of the report is to make recommendations for restoring the vegetation on Alameda Creek in the study area to conditions suitable for a trout fishery. Review of the land uses in the study area has demonstrated that management practices associated with grazing and gravel mining combined with decreased creek flows through the study area created by the damming of Calaveras and San Antonio creeks are the major contributing factors to riparian vegetation degradation in the study area.

An important factor affecting trout habitat in the study area based on the fisheries studies is the maintenance of favorable stream water quality particularly as regards water temperature. Degradation to the present streamside vegetation throughout the study area reaches plays a major role in water temperature control because shading from riparian canopy cover substantially lowers the creek water temperatures. At present, Reach 1 has the only substantial riparian canopy cover and even there this cover has been considerably degraded and is presently estimated at only 60 percent on average. Although the fisheries studies have demonstrated the need for increased stream flows to establish a viable fishery in the creek, they have not answered the question of whether present flows through the creek are limiting the recovery of the riparian vegetation. In order to answer this question, Ogden analyzed whether current site hydrology might limit the recovery of riparian vegetation in the study area. Section 3.1 will discuss this analysis in detail.

The remaining parts of this section will discuss restoration recommendations for each reach of the study area. In general, it is Ogden's conclusion that management changes combined with time rather than active revegetation planting *per se* should be the means of revegetating the creekway because such an approach is likely to succeed and be cost-effective. Cost estimates are given for the restoration approach(es) recommended for each reach to guide further decision making. Because a management appoach rather than a landscaping approach to revegetation appears to be best, the present report will only include preliminary revegetation plant palettes and a sample construction/post-construction maintenance and monitoring plan which would need to be further refined if revegetation landscaping proceeds.

3.1 Study Area Vegetation Hydrology Analysis

Probably the most serious problem limiting a trout fishery in the study area is the lack of sufficient stream flow resulting from the construction of Calaveras Dam. Reach 1 of the study area has shown reasonable promise for development of a trout fishery if Calaveras Dam releases are increased to approximately 15 cubic feet per second (cfs) on a continual basis from May to October (Biosystems 1993). This water flow would be supplemented in the winter months by a flow of approximately 20 cfs (Hagar 1993) from natural runoff within the watershed. However, the current fisheries analysis does not specifically address the issue of whether riparian vegetation recovery within the watershed, which has been historically degraded is limited by present water supplies or other hydrological considerations. Two issues need to be looked at in this regard. The first of these is the

evapotranspiration needs of the riparian vegetation in the study area. If current waterflows through the drainage are insufficient to support riparian tree coverage then such vegetation will be unlikely to recover over time even if other factors degrading it such as grazing are removed. Secondly, since a shallow depth to water table plays such an important role in establishing and maintaining riparian vegetation cover, there is a need to analyze whether modifications to study area surficial geology or hydrology could affect the potential for riparian vegetation recovery in the study area.

In order to estimate the quantity of water needed for evapotranspiration by riparian vegetation in the study area , Ogden has utilized the California Irrigation Management System (CIMIS) for estimating water use on agricultural crops. This system allows a crop manager to estimate water use on crops by using the formula ETo x Area = Water Use where ETo is the evapotranspiration rate for a given area as measured seasonally at local weather stations. ETo is further modified by a crop factor K which modifies ETo to account for the water use of a particular crop (some crops use more water then others). Ogden has found that 100 percent of seasonally adjusted ETo should be assumed for riparian vegetation areas (Young 1942). The CIMIS system utilizes weather stations located throughout California to provide local ETo rates to farmers. Since this project is not directly adjacent to a data collection station, the ETo rate used for the present calculations was based on an average of the historic rates documented for the San Jose and Davis measuring stations (52.7 inches annually at Davis and 47.1 inches annually at San Jose. Thus ETo times riparian area acreage gives the water loss for any stretch of the creek.

For the purposes of this study, Ogden assumed a 40-foot wide fully vegetated riparian corridor. Reach 1 was assumed to have a length of approximately 24,000 feet, Reach 2: 7,000 feet, and Reach 3: 9,000 feet up to the 680 Highway. Based on these assumptions full riparian cover within the study area would constitute 22 acres in Reach 1, 6.4 acres in Reach 2, and 8.3 acres in Reach 3; or approximately 37 total acres. ETo was calculated to be 4.2 feet per year based on our assumptions or 0.63 feet per month during the peak use month of July (Average July ETo = 7.5 inches). It was also known that the historic seepage rate under the Calaveras Dam to the drainage was 0.5 cubic feet per second or 29.8 acre-ft. per month or 358 acre-feet per year. Based on these parameters approximately 154 acre-feet of water would be needed to sustain a fully vegetated riparian corridor every year or less than half of what seeps under the dam. Looking at this situation more closely during the critical dry peak use month of July, 22.9 acre-feet of water would be needed to

sustain a fully vegetated riparian corridor but nearly 30 acre-ft. are supplied to the drainage from dam seepage. Therefore, if all water currently seeping through the dam went merely to sustain riparian vegetation cover there should be enough to sustain a fully vegetated corridor. The study area drainage appears to be receiving water at a rate more than double that necessary to sustain a high quality riparian vegetation corridor throughout the study area.

The second hydrological factor which is probably more significant than water supply in determining the potential for revegetation within the study area is the depth to water table. In examining the different reaches of the study area, depth to water table does not appear to be a problem in Reach 1. In this reach the creek runs over fairly steep topography and depth to water table is estimated to be less than 5 feet in almost all areas. Such a depth is more than adequate to sustain riparian vegetation cover. In fact, too shallow of soils covering the bed rock geology in this reach actually limits vegetation establishment in some parts particularly in the steep drop from the dam to the Calaveras Creek confluence with Alameda Creek where the creek passes mostly over bedrock.

This situation is very different in Reaches 2 and 3 where a deep alluvial gravel layer estimated at approximately 20 to 50 feet in depth covers the valley floor. Here the stream has historically disappeared below the surface except in wet months during winter and spring (Erlewine 1993). This has historically resulted in a greater depth to water table which predicated the establishment of a more xeric riparian cover consisting of a vegetation dominated by mulefat and sycamore. Gravel mining of this area has probably further increased the depth to water table since the pits created by such excavation tend to draw down the water table in their vicinity. There has been some attempt to isolate these draw down effects by requiring the construction of clay cutoff walls between the creek channel and the mining pits but this effort has been localized and incomplete. It is estimated that the capacity of the original below ground shallow (<40 feet deep) aquifer in this area was approximately 5600 acre-feet. Gravel mining has removed about half of this, however, it has added approximately 20,000 acre-ft of above ground storage capacity to the area of which about half is full throughout the year. At present the water table appears to have stabilized approximately 20 feet below the present creek channel surface although occasional storm flows during the winter months return it for short periods to the surface. Since present flows from the dam seepage alone appear sufficient to keep the aquifer filled, it appears that the prospect of returning the water table near enough to the surface to create riparian cover on the one hand and/or establish perennial surface flow is unlikely to be

possible except by utilizing expensive and artificial methods such as the creation of an artificial impermeable soil layer at 5 feet below the surface under the stream channel. Therefore, it appears that the main wetland habitat values which are possible in this area will be those associated with the ponds being created by the gravel pits. And, while these could be significant, they will not be relevant to the establishment of trout habitat in these reaches.

In conclusion, site hydrology does not appear to be any more restricting today then historically in the establishment of riparian vegetation cover within the three reaches of the study area. In fact there is now a greater likelihood of riparian vegetation establishment around the gravel pit lakes to be left after excavation is completed than there was formerly in the Reach 2 and 3 areas. It may be expected that if additional water were released into these lakes as a result of a trout fishery improvement program in Reach 1 that additional riparian vegetation acreage could establish around these lakes as their perimeter is enlarged. However, it should be emphasized that additional water releases in the creek drainage through the study area while not critical to riparian habitat development may play an important role in clearing out creek bed areas which have become dominated by cattails and algal mats due to the current low flows during the summer. Thus Ogden supports the increase of water releases recommended by the fisheries biologists as a means to establish better pool and riffle environments within Reach 1 of the creek.

3.2 Reach 1: Calaveras Dam to the Treatment Plant

3.2.1 Grazing Exclusion

Once adequate stream flow is restored to this reach as recommended by the fishery biologist (Biosystem 1993), Ogden feels that the exclusion of grazing is the single most important measure for the restoration of riparian vegetation. Cattle grazing has continuously degraded vegetation along the edges of the creek and in some sections has done damage to bank structure. Complete removal of grazing from this reach is recommended. Preliminary investigations with both the SFWD lease manager and the EBMPD lease manager indicate that such exclusion would not be detrimental to the continued use of the rest of these leaseholds for grazing purposes. There appears to be sufficient water resources available in other parts of these leases to sustain a grazing practice. Since only the western portion of the watershed in this reach is presently leased for grazing purposes, Ogden recommends the installation of a 4-foot-high 3-strand barbed

wire fence with an electric wire along its top on the western border of Calaveras Road as the most expedient means of cattle exclusion from the creek areas. Fencing would then be extend east along the northern boundary of lease G to the edge of Alameda Creek and then south along the creek edge until topography or the reservoir prevented further cattle intrusion into the creekbed. To the north, fencing should extend along the western and northern borders of the treatment plant and then across Alameda Creek at the Calaveras Road Bridge Crossing. Flood release fencing should be installed across the creek to allow the stream to pass but to keep cattle out. See Figures 2 and 3 for the proposed location of this fencing.

Care should be taken in any fencing program to provide supervision of the effort by a qualified biologist to assure best fence location and minimal damage to desirable native vegetation in the process. In addition, a monthly program of fence inspection is recommended for the first year after installation and then quarterly thereafter to assure that the fencing is kept intact and functional. In addition, provisions should be added to all grazing leases for the notification of the lease manager by the leaseholder when any breach of fence is discovered. Leaseholders should be responsible for the repair of all fencing within one week of discovery.

It may also be necessary to monitor and limit human access to the creek on its eastern side from users of the campground and picnic area. At present, however, it is felt that elimination of cattle grazing alone would be sufficient to allow volunteer riparian growth to regenerate throughout this reach.

3.2.2 Elimination of Cattails and Algal Mats

The extensive beds of cattails and thick algal mats presently found in this reach are probably the result of lowered water flows resulting in sedimentation and stagnant water conditions combined with higher water temperatures brought on by lack of vegetation cover due to grazing. Ogden believes that regular water releases in the watershed combined with grazing exclusion will significantly decrease these minor problems. High water flows resulting from major storm events should gradually wash out the sediments which the cattails depend upon and shade created by better vegetation cover along the stream channel would cause the cattails to die out over time. Algal mats should also disappear when water temperatures drop and shade levels rise.

3.2.3 Costs

It is estimated that the following costs would be associated with this riparian restoration proposal for Reach 1:

Electric barbed wire fence installation (26,400 ln. ft. @ $2.40 ln. ft.)	$ 63,360.00
Supervising biologist for fencing (lump sum)	$ 3,000.00
Annual fence repairs (estimated at 5% of installation costs for 10 years)	$ 31,680.00
Total:	$ 98,040.00

3.2.4 Conclusion

In conclusion, Ogden believes that full revegetation of Reach 1 can be accomplished through a combination of grazing exclusion and fishery water releases from Calaveras Reservoir. More active revegetation measures such as seeding or container planting are not recommended at this time; however, a reevaluation of Reach 1 is recommended after completion of a five-year initial management plan following the current set of recommendations. At that time additional measures including remedial plantings should be considered if the present set of management recommendations are insufficient to assure adequate revegetation or fishery success.

3.3 Reach 2: Water Treatment Plant to Hetch Hetchy Aqueduct Crossing Restoration Recommendations

3.3.1 Riparian Corridor Restoration

Ogden has concluded after review of historic aerial photos of this area that this reach of the creek was historically covered with only sparse riparian cover. Dams in the Niles Canyon area now exclude migration of trout or steelhead from the bay up the creek through this area. Further, there appears to be little potential for increasing water releases to this reach sufficient to bring the water table back to the surface.

It would, however, be desirable from a general wildlife habitat and corridor perspective, to restore native upland and riparian vegetation cover to this reach of the creek. Ogden recommends serious consideration of such an effort, but makes it clear that such an effort appears to have little relevance to the improvement of a stream trout fishery. Ogden also recommends that even if such a plan is not followed, sufficient surface flow should be

preserved immediately downstream of the water treatment plant to maintain the existing high quality riparian woodland cover established there.

3.3.2 Costs

The costs for restoration of this area will be directly tied to the restoration of the Reach 3 area since they both have similar hydrology. Therefore, Ogden will include a discussion of restoration cost alternatives for this reach in the Reach 3 discussion which follows.

3.3.3 Conclusion

Ogden concludes that while the development of a viable trout fishery is not feasible in the Reach 2 area, the restoration of a high quality riparian wildlife corridor is both feasible and desirable.

3.4 Reach 3: Hetch Hetchy Aqueduct Crossing to Highway 680 and on to Arroyo de la Laguna Restoration

3.4.1 Analysis and Recommendations

Analysis of this portion of the creek suggests that it is unlikely to have future value as trout habitat and had only spring spawning value historically (Hagar 1993). It is likely that the area will remain highly disturbed for the immediate future due to the gravel mining operations; however, Ogden believes there would be value in considering eventual restoration of a riparian wildlife corridor here as in Reach 2. The primary means of habitat restoration would be an active revegetation program combined with the exclusion of grazing. The gravel pit lake edges should naturally revegetate themselves with riparian cover; however, a more active revegetation effort would accelerate habitat establishment and would add greater diversity to the habitats created. Upland areas would require an active revegetation effort to be successful. Because of the significant disturbance to the landscape caused by the gravel mining operations, including the creation of several large pit-lakes, the possibility also exists to connect the water features into an overall integrated riparian network of stream channel and lakes. Such an effort would require significant regrading of the present stream channel to realign it with the lake features but some of these costs might be carried by the mining operators themselves as part of their required restoration effort. Such an approach would have the added advantage of connecting all

riparian areas into one wildlife corridor system. This alternative could also utilize active landscaping with native species to speed up the revegetation effort and add diversity which will otherwise not be present. If such revegetation programs are instituted, it is recommended that they be put together by a recognized revegetation specialist and that a minimum five-year monitoring and maintenance period with success standards be instituted to assure success. There would be potential in such a restoration program for recreational values associated with fishing in the lakes and other passive uses.

Current "restoration plans," which have been approved for revegetation of the gravel pits, after mining is completed (see Appendix A), appear inadequate to achieve much biological value since they show only screening vegetation and do not specify native riparian species. At a minimum, Ogden recommends that these gravel pit restoration plans be reviewed by the SFWD and that an attempt be made to use only native riparian and upland species in the revegetation effort that would have been found in the area prior to mining. Ogden has included a general species palette for such an effort as Appendix B of this report. Ogden has also included a general maintenance and monitoring program with success standards for such an effort as Appendix C of this report. Any revegetation program should incorporate these elements into its final design, installation, and monitoring requirements.

3.4.2 Costs

Costs for the restoration/revegetation of a wildlife corridor through Reaches 2 and 3 will be considered together because they both have a similar subsurface hydrology which dictates similar habitat types.

Ogden has concluded four progressively more expensive scenarios exist for future site restoration. Option 1 would be to merely exclude grazing from the floodplain areas and rely exclusively on natural revegetation to regenerate cover. This option would only regenerate native species cover dependably along the gravel pit lake edges through natural invasion. The remaining areas are likely to be invaded by a variety of non-native weed species. Option 2 would be to exclude grazing from the floodplain and then to actively revegetate the upland areas with non-irrigated native seed mixes leaving the riparian to regenerate on its own. This and all other options would require an active maintenance and monitoring program for a minimum of 5 years after installation. Option 3 would intentially relocate the present stream channel through the series of gravel pit lakes left after mining is completed. This option adds the additional costs for regrading, mainly in Reach 3. It

would also involve grazing exclusion as in Option 2 but would continue to rely on natural regeneration of riparian cover and non-irrigated seeding of upland areas. Option 4 would be to relocate the channel through the lakes, exclude grazing, and actively revegetate the channel and upland areas. Temporary irrigation of the riparian areas would also be included in this option. Ogden concludes at this time that no one alternative can be clearly recommended since a variety of budgetary, political, and biological factors need to be considered by SFWD before a final decision can be made. It is important to remember, however, that none of these options anticipate the return of a trout fishery to this stretch of the channel although fishing for other species might be incorporated into the gravel pit lakes. In general, the more active revegetation strategy would shorten the time to create new riparian habitat, would assure the establishment of native upland habitat, and would allow for greater control of the species composition of the site. Below is a cost accounting for each option.

Option 1: Exclude Grazing

Electric barbed wire fencing to exclude grazing from Reach 2 (west side of drainage only: 7000 ft.@$375/acre-ft.)			$ 16,800.00
Electric barbed wire fencing to exclude grazing from Reach 3 (west side of drainage only: 9000 ft.@$375/acre-ft.)			$ 21,600.00
Cost of lost grazing acreage			unknown
		Total:	**$ 38,400.00**

Option 2: Exclude Grazing, and Revegetate Upland Areas

All same costs for Option 1			$ 38,400.00
plus add following cost:			
Cost to revegetate uplands (assume 235 acres in Reach 3 and 30 acres of 100 in Reach 2)			
Site Prep	20¢/sq. ft. or	@$8,700/acre	$ 2,305,500.00
Seeding	6¢/sq. ft. or	@$2,600/acre	$ 689,000.00
Reseeding for 2 years		@10% of initial costs	$ 68,900.00
5-year monitoring costs		@$15,000/yr.	$ 75,000.00
5-year maintenance costs		@$20,000/yr.	$ 100,000.00
		Total:	**$ 3,276,800.00**

Option 3: Exclude Grazing, Regrade Channel* and Revegetate Upland Areas

All same costs as Option 2 would be incurred plus add following costs:				$ 3,276,800.00
Costs to regrade channel in Reach 3 through lakes (8000 ft. x 40 ft. x 3 ft. @$3.50/cu. yd.)				$ 124,450.00
			Total:	**$ 3,401,250.00**

Option 4: Exclude Grazing, Regrade Channel*, and Revegetate Upland and Riparian Areas

All the same costs as for Option 3 would be incurred plus add following costs:				$ 3,401,250.00
Cost to revegetate 40-ft.-wide channel = 14.7 acres				
Landscape Construction and Grading Documents				$ 25,000.00
Irrigation costs	45¢/sq. ft.	or	@$19,600/acre	$ 288,100.00
Site Prep	20¢/sq. ft.	or	@$8,700/acre	$ 127,900.00
Container planting costs**	28¢/sq. ft.	or	@$12,000/acre	$ 176,400.00
Seeding costs	6¢/sq. ft.	or	@$2,600/acre	$ 38,200.00
Reseeding costs			@5% of initial costs	$ 1,900.00
Dead plant replacement costs			@5% of initial costs	$ 8,800.00
Extra plantings around lakes (assume 5 acres @$16,600/acre seed and container plants)**				$ 73,000.00
			Total:	**$ 4,140,550.00**

* Note: Some or all of the additional costs for this alternative could be paid for by the gravel pit companies as part of their required restoration efforts.

** Note: Based on approximately 1700 1-gallon plants per acre.

3.4.3 Conclusions

Ogden concludes that, as with Reach 2, although a viable trout fishery does not appear feasible, Reach 3 can be restored to a high quality riparian wildlife corridor. Four possible options have been proposed for such a restoration effort ranging from merely restoring surface hydrology and excluding grazing to the most intensive alternative which would be active regrading and relandscaping of the floodplain area. Ogden believes the most desirable alternative from a multiple use perspective would be the active restoration of the floodplain area after gravel mining operations are completed to a series of gravel pit lakes connected by a new stream channel. This is also the most expensive of the alternative restoration scenarios to implement. It may be possible to obtain some of these restoration monies from the present sand and gravel operators as part of their requirement to restore the site once their operations cease. From a timing stand point, the restoration of this reach

does not appear likely in the near future because sand and gravel operations will continue to disturb the floodplain areas for probably at least another decade.

4.0 NURSERY RIPARIAN IMPACT ANALYSIS

4.1 INTRODUCTION AND METHODS

As part of the trout habitat restoration feasibility analysis, Ogden was charged with gathering information to determine if present nursery leasing in the lower reaches of the study area has any effect on the restoration of the area for trout habitat. Ogden initially determined that there were several ways in which nursery practices might affect habitat quality in the area. First, if water were drawn directly from the water table in the vicinity of the nurseries then the water table might be drawn down to levels below which riparian species could survive near Alameda Creek. On the other hand, it might be possible that runoff waters from the nurseries would add sufficient water to the stream channel to actually enhance riparian vegetation establishment. Second, there was the question of whether runoff from the nurseries might be contributing either fertilizer salts or pesticide residues to the water table and/or stream flow which would be detrimental to the riparian ecology.

In order to answer these questions Ogden created a short questionnaire which was sent to the manager at each nursery. A sample of this questionnaire is shown in Appendix D of this report. This questionnaire attempted to determine water use, fertilization, and pesticide/herbicide practices at the nurseries to help answer the above questions. This questionnaire was then forwarded to the nursery managers by Tim Koopman, lease manager for SFWD, and when responses were received, they were returned to Ogden for analysis. Copies of the returned questionnaires are included in Appendix B of this report.

Responding

Dell's Ivy Acres Nursery
Hi C Nursery
Naka Nursery
Nagata Farm
Pacific Nurseries of California, Inc.
Valley Crest Tree Company

Not Responding

Jeff Anhorn Nursery (late response not included in present results analysis)
John Ura

4.2 Nursery Questionnaire Results

There are eight nurseries which presently lease land in the study area. Three of these are the primary lessees while five of the nurseries sublease land from the primary lessees. Figures 2 and 3 show the locations of these leaseholds. Pacific Nursery, Naka Nursery, and Valley Crest Tree are the primary leaseholders. It should be noted, as shown on these figures, that not all of the land leased is currently under production. Ogden received responses from six of the eight nurseries (a seventh was received after report preparation was completed) and it is believed the conclusions derived from these surveys are similar to those which would have been reached for the non-reporting nurseries. The surveys showed the following results:

4.2.1 Irrigation Practices

The source of irrigation was the first question which Ogden sought to answer, since the water table depth, and therefore riparian vegetation cover, could be detrimentally affected if nurseries were drawing their water from ground wells onsite. It became clear after a minimal amount of research that all nurseries currently draw their water needs through pipes from the water treatment facility directly upstream (Koopman 1993).

One hundred thirty-two acres (68 percent) are reported to be under drip irrigation, 26 acres (13 percent) are under conventional sprinkler irrigation, 33 acres (17 percent) are hand watered, and 3 acres (2 percent) receive one annual furrow irrigation. Eight acres at Hi-C Nursery were reported to receive both spray irrigation and hand watering; thus, 194 acres are reported for the various types of irrigation but only a total of 186 acres is in production.

Only two of the growers knew their annual water consumption. Most growers reported only that they irrigate based on plant need, the weather, visual inspection of the stock, and their experience. They report growing everything from bedding plants to boxed trees and there is one 3-acre orchard among the responses.

Questionnaire results suggest that irrigation is probably not planned to correspond to evapotranspiration loss at most of the nurseries and there is probably some wastage as a result. This conclusion is further supported by the two nurseries which did report annual water usage: Dell's Ivy Acres and Pacific Nurseries. Dell's utilized abut 1.6 acre-feet of water per year per acre of production using only overhead irrigation while Pacific Nurseries utilized 3 acre-feet per acre per year using both drip and overhead systems. Assuming an annual evapotranspiration rate of 49.9 inches, which is an approximation for the area using the historical averages for San Jose and Davis, 4.2 acre-feet per year per acre would be needed to meet annual evapotranspiration needs. Based on this need, Dell's Ivy Acres Nursery is applying about 38 percent of the annual evapotranspiration rate and Pacific Nurseries is applying about 70 percent. Thus both nurseries reporting water usage appear to be well within the evapotranspiration requirements of their crops and runoff would probably only take place if excess irrigation was occurring during part of the year. This does not appear to be the case. None of the growers reported substantial irrigation or storm runoff. The fact that 68 percent of the acreage is watered by drip irrigation would further support this conclusion since drip irrigation systems usually apply irrigation at rates too low to create substantial runoff.

4.2.2 Fertilizer and Pesticide Use

All operations stated that they fertilize their stock. Three of the six nurseries, representing 20 percent of the acreage, incorporate fertilizer into the soil or container while 80 percent of the acreage is fertilized using fertilizer injected into the irrigation water. Growers report using a wide variety of fertilizer products as well as varying rates of application. The grower who incorporates the fertilizer into the container potting mix reports using about 0.63 tons per acre annually while the other growers incorporating the fertilizer into the field soils report the use of only 0.10-0.50 ton per acre annually. Growers using daily fertilizer injection also show variation with one reporting 0.88 tons per acre of use annually and another reporting only .0005 tons per acre annual use (nitrogen and phosphorus only) and the third grower not knowing what is used. Nevertheless, despite these varying rates, Ogden believes that the rates of irrigation reported are not likely to create sufficient runoff to contaminate ground-water supplies with excess nutrients nor do the rates of fertilizer use seem high enough to create a contamination problem even if there were much higher levels of runoff. The following pesticides (by trade name) are reported to be used on a regular basis:

Herbicides:	Ronstar
	Roundup
	Simazine
Insecticides:	Diazinon
	Malathion
	Orthene
Fungicides:	Bayleton
	Daconil
	Subdue

The following additional pesticides (by trade name) are reported to be used on an as-needed basis:

Herbicides:	Expedite
	Scott OH II
	Surflan
Insecticides	Avid
	Dursban
	Lindane
	Maverick
	Sevin
	Triforine
	Volck oil
Bactericide:	Agri-strep
Fungicides:	Fungo Flo
	Benelate
	Plantax
	26019

Without further ground-water testing it is impossible to tell whether any of these pesticides are entering the water table; however, as with fertilization, the fact that the majority of the acreage (80 percent) is being irrigated using low runoff drip irrigation equipment suggests that the effect of these chemicals on the stream ecology or water table is probably minimal. In addition, present pesticide rules and regulations require the storage of all these products in leakproof containers inside a locked storage area.

4.3 Conclusions and Recommendations

The results of the nursery surveys indicate that the continued leasing of nursery properties along the creekway is not incompatible with the restoration of a riparian corridor in the two lower reaches of the study area as discussed in the previous section of this report. The

nurseries do not draw water directly from the water table, nor do they at present appear to contribute either substantial runoff, or pesticide or fertilizer leachates to the water table or the stream channel. This is, however, a general conclusion based only on the results of the current nursery surveys. It would only be possible to ascertain whether pesticide or fertilizer leaches into the water table by performing lab tests of water taken from this water table. While Ogden does not recommend such an effort at this time, the SFWD may wish to undertake such studies in the future, particularly if they wish to recover water from the aquifer.

Ogden would recommend that if better planned programs of water management (based on CIMIS) and pesticide/fertilizer application were required of lessees by the SFWD, then less water would be wasted and the potential for leachates entering the water table would be further minimized.

5.0 REFERENCES

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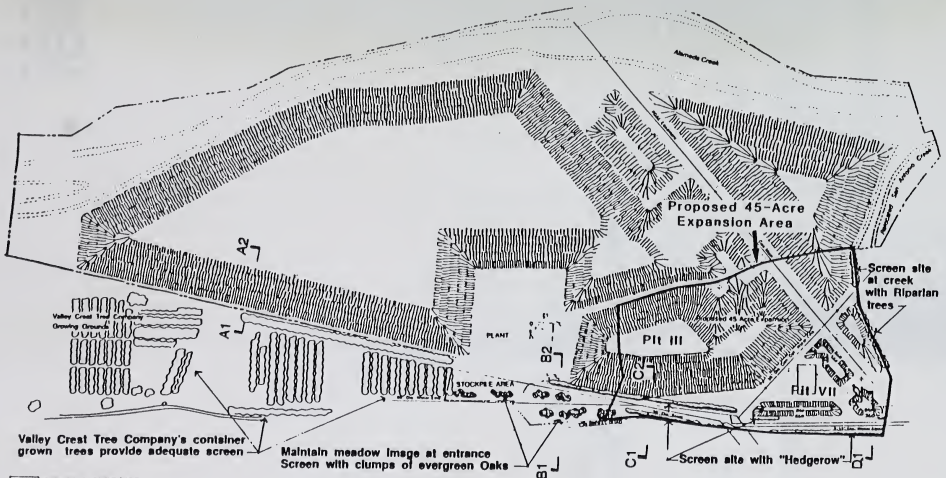
Young, Arthur A. and Harry Blaney. 1942. Use of water by native vegetation. California Department of Public Works, Division of Water Resources. Bulletin 50. 160 pp.

APPENDIX A

GRAVEL MINING RESTORATION PLANS

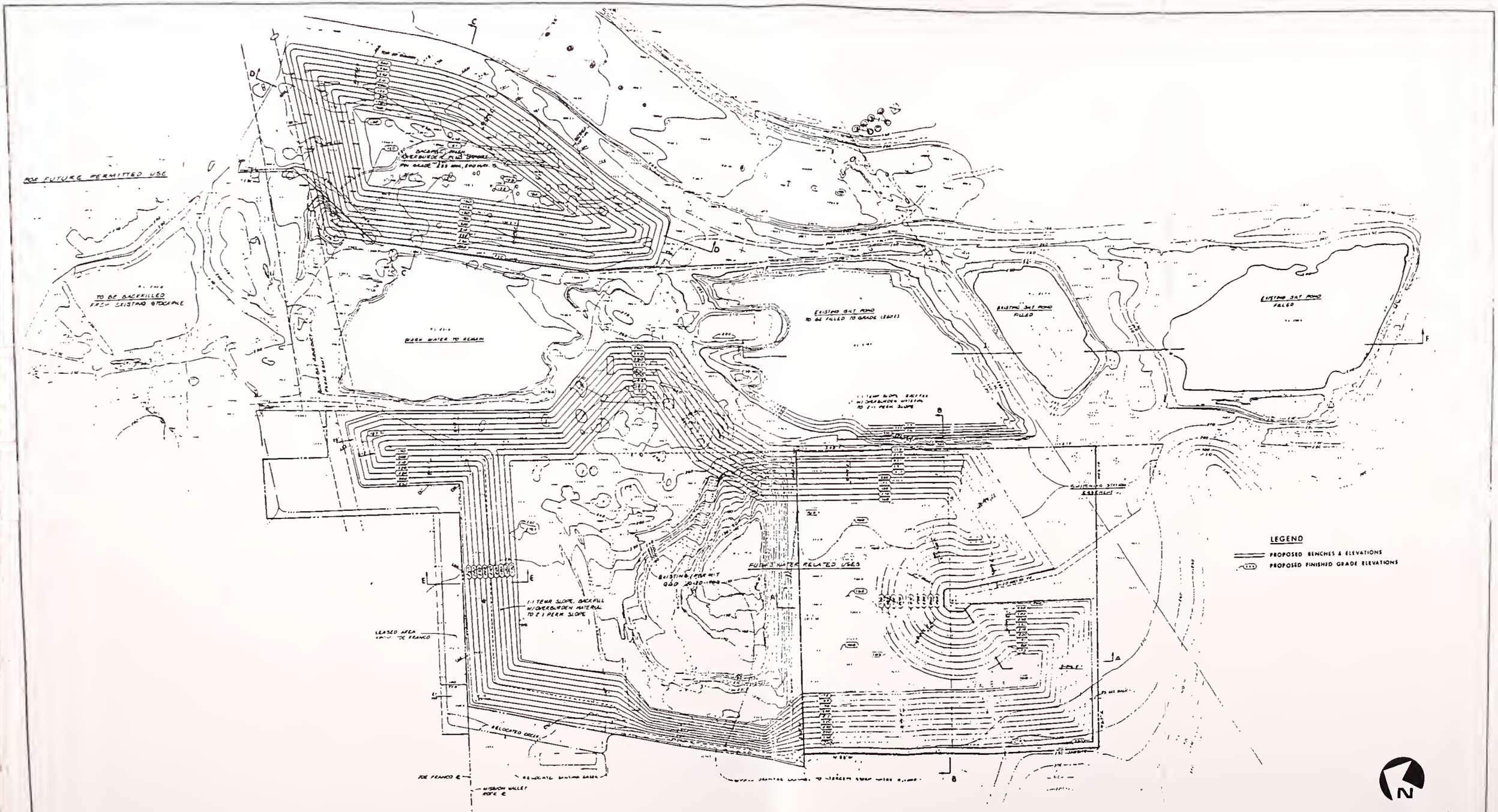


OGDEN

RMC Lonestar: Proposed Gravel Quarry Restoration Plan

APPENDIX

A



OGDEN

Mission Valley Rock: Proposed Gravel Quarry Restoration Plan

APPENDIX

A

APPENDIX B

SAMPLE PLANTING PALETTES FOR RIPARIAN REVEGETATION AT ALAMEDA CREEK

(Note: These palettes will need further refinement before final design.)

Willow/Mulefat Woodland

Container Plants

	Size	#/acre	Diameter of Individual Cover	% Total Cover
Overstory				
Goal: 100% mature canopy cover				
Alnus rhombifolia	1 gal.	167	10 ft.	30
Baccharis glutinosa	1 gal.	223	6 ft.	15
Platanus racemosa	1 gal.	80	10 ft.	15
Salix laevigata	1 gal.	160	8 ft.	20
Salix lasiolepis	1 gal.	298	6 ft.	20
Subtotal		928		100%
Understory				
Goal: 20% mature canopy cover				
Carex sp.	1 gal.	276	4 ft.	40
Juncus xiphioides	1 gal.	207	4 ft.	30
Mentha cruensis	1 gal.	104	4 ft.	15
Toxicodendron diversilobum	1 gal.	104	4 ft.	15
Subtotal		691		100%
Total		1736		

Hydroseed Mix

	lbs./acre
Artemisia douglasiana	3
Carex sp.	3
Stachys pycnantha	1
Total	7

Riparian Oak/Sycamore Woodland

Container Plants

	Size	#/acre	Diameter of Individual Cover	% Total Cover
Overstory				
Goal: 80% mature canopy cover				
Platanus racemosa	50% 15 gal.	37	15 ft.	15
	50% 5 gal.	37		15
Acer macrophyllum	1 gal.	50	15 ft.	20
Quercus agrifolia	15 gal.	69	20 ft.	50
	Subtotal	193		100%
Understory				
Goal: 20% mature canopy cover				
Aesculus californica	1 gal.	38	8 ft.	22
Rhamnus californica	1 gal.	62	4 ft.	9
Eriogonum fasciculatum	1 gal.	48	4 ft.	7
Heteromeles arbutifolia	1 gal.	31	6 ft.	10
Symphoricarpos sp.	1 gal.	48	4 ft.	7
Sambucus mexicana	1 gal.	24	8 ft.	14
Toxicodendron diversilobum	1 gal.	131	4 ft.	19
Umbellularia californica	5 gal.	31	5 ft.	7
Zauschneria californica	1 gal.	62	3 ft.	5
	Subtotal	475		100%
	Total	**668**		

Note: Numbers per acre and percent total cover by species will be allowed to vary within 20 percent of their present values to accommodate the ecological profile of the site.

Riparian Oak Sycamore Woodland

Hydroseed mix

	lbs./acre
Artemisia californica	1
Eriogonum fasciculatum	4
Artemisia douglasiana	3
Bromus mollis	2
Elymus glaucus	4
Festuca megalura	2
Lotus scoparius	4
Lupinus succulentus	4
Stipa pulchra[1]	3
*Thalictrum polycarpum**[2]	1
Total	**28**

* Special collection.
[1] To be raked in before hydroseeding takes place.
[2] To be seeded individually by project biologist.

Marsh

Container Plants

	#/acre	Diameter of Individual Cover
Juncus xiphioides	100	2 ft.
Scirpus californicus	500	6 ft.
Carex sp.	500	2 ft.
Total	**1100**	

Note: Collection locations to be provided by project biologist.

Coastal Sage Scrub

Non-irrigation Hydroseed Mix

	lbs./acre
Artemisia californica	3
Eriogonum fasciculatum	15
Eschscholzia californica	1
Festuca megalura	3
Haplopappus venetus	4
Lotus scoparius	3
Lupinus bicolor	4
Mimulus longiflorus	2
Salvia mellifera	2
Stipa pulchra •	3
Total:	**40**

• Seed to be raked in before hydroseeding takes place.

APPENDIX C

SAMPLE CONSTRUCTION/POST-CONSTRUCTION MAINTENANCE AND MONITORING PROGRAM

(Note: This Design, Installation, and Monitoring Plan is from the Home Capital Development Company's 15-acre Riparian Revegetation Plan for the Rancho San Diego Development near San Diego, CA. As such, it would need to be modified to suit the site conditions and design parameters of the Alameda Creek Restoration Plan.

SECTION 1
DESIGN AND INSTALLATION OF THE MITIGATION PLANS

1.1 FORMAT AND METHODS

This section delineates the specifications for the landscape plans for each of the proposed revegetation areas. The installation specifications in this conceptual mitigation plan will be incorporated into the final landscape plans for this project and will be included as an addendum to all construction documents. All final construction documents will be approved by a qualified riparian revegetation designer before they are let for bid.

1.2 DESIGN CRITERIA

1.2.1 Qualifications and Responsibilities of Persons Developing Plans

A qualified riparian revegetation designer will work with a landscape architect registered in the State of California to develop final landscape plans, and with a civil engineer registered in the State of California to develop final grading plans for the revegetation sites. The revegetation designer will approve all final grading plans developed by the civil engineer. The revegetation designer will develop planting layouts and consult with the landscape architect in the design of the irrigation layout and final set of planting specifications. The landscape architect will be responsible for the preparation of final planting plans, irrigation plans, and specifications. The revegetation designer will approve all final landscape drawings and specifications before these plans are issued for bid. The landscape architect will be responsible for the preparation of an installation cost estimate for the project which will be used for bonding and bidding purposes.

The revegetation designer shall have the following minimum qualifications:

1. Training and/or local experience in growing the native plant species used in the project (either in a nursery setting or in the field).

2. Knowledge of the vegetation associations proposed for the revegetation effort, including species identity, general composition for both overstory and understory, and species' ecological positions relative to the water table.

3. A minimum of 2 years of practical horticultural experience, i.e., maintenance and/or growing and propagating of plants.

4. A minimum of 2 years of study and 2 years of field experience in landscape design and construction, including a knowledge of both irrigation system design and planting plan development.

1.2.2 Requirement for Formal Landscape Plans

The specifications of this conceptual mitigation plan will be used to develop and be incorporated into a formal set of installation documents for each revegetation area which will include a grading plan if necessary, a planting plan, an irrigation plan, and a set of installation specifications. This plan will also be used as the basis for post-construction maintenance and monitoring procedures specified in Sections 4 and 5.

1.3 Installation Specifications

This section covers all activities relating to the installation of landscape plans, including contractor education, construction timing, site protection, grading, irrigation installation and frequency, general planting specifications, contract growing, substitutions, sources, and guarantees.

1.3.1 Contractor Education

Before the beginning of any grading or installation work, all contractors who will complete some aspect of the plans will meet at the site with the project revegetation designer. The revegetation designer will provide a copy of this document to each contractor and will review all aspects of the plan which concern the contractor including site protection, inspections, landscape procedures, and guarantees. It shall be made clear to the contractor(s) that the revegetation designer will have final supervisory control along with the landscape architect over field installation.

1.3.2 Timing of Construction

No grading or heavy equipment operation shall take place at the revegetation sites during the nesting period for the least Bell's vireo (March 15 through September 15) due to

possible noise impacts. The exact end of the nesting period should be determined via vireo surveys to determine actual departure of the vireos. Should vireos not arrive at the site by the middle of June in any given year, this activity restriction may be waived with approval of the resource agencies. Hand planting without machinery may, however, take place through April 15th. Revegetation areas may be landscaped (i.e., irrigated and planted) at any time of year as long as associated activities are conducted within the necessary noise parameters established for protection of vireo habitat. Generally, noise levels within the habitat must be under 60 dBA as an hourly average (SANDAG 1990). As a guide, equipment operating at least 1400 feet from the habitat usually meets this requirement. The installation of the project will be scheduled in such a way that any required grading can be accomplished during the same year as the irrigation and planting installation. It is intended that the landscape installation immediately follow grading and clearing operations without delay.

1.3.3 Site Protection

Protection During Construction

Existing riparian and other desirable native vegetation will be protected during the construction process by temporary construction fencing. Construction fencing will limit access in the revegetation areas to workers and machines implementing the plans. It will also assure that the existing riparian vegetation and buffer zone vegetation are not damaged during the installation of the revegetation work. The revegetation designer will flag the limits of the work areas prior to grading or clearing operations for each of the revegetation sites. A 6-foot temporary chain link fence will be erected at the limits of existing riparian habitat where grading will take place. This fencing will remain in place until all grading and/or excavation work is completed. At that time, upon approval by the revegetation designer, the fencing may be removed if other construction activities will not harm existing riparian vegetation. On sites which will not be graded, including adjacent buffer zone areas, the limits of work will be clearly marked by the contractor using a temporary 4-foot high fence of wood or metal posts with a single strand of 3/8 inch yellow nylon rope strung between the posts. An exception to this practice will be allowed in narrow revegetation corridors such as those on Site II; they may be fenced off at their access points rather than along their edges at the discretion of the revegetation designer. Such fencing will remain in place until the end of the construction process or until the revegetation designer considers it no longer necessary.

The project revegetation designer will certify in writing to the San Diego County Department of Planning and Land Use (SDDPLU) that the limits of the work area have been properly fenced before the contractor may proceed with installation. If at any time workmen or machinery damage vegetation outside the limits of work, the contractor will bear the full cost of having the revegetation designer complete a restoration plan for the additional area, as well as the costs for monitoring the success of the revegetation according to the same standards as the original revegetation. The contractor will also be responsible for repairing all damage to protective fencing within one week of such damage.

Temporary 4- to 6-foot high chain link construction fencing, or 4-stranded barb wire fencing if approved as appropriate by the revegetation designer, shall also be placed along all borders of the revegetation areas where any other site construction work might impinge upon the revegetation site boundaries. This fencing may also be the same as the fencing required along the boundaries of the 100-foot Riparian Open Space Buffer, or the equestrian trail, if so approved by SDDPLU. It will remain in place at least until the adjacent construction work is completed. The project revegetation designer will have final discretion over protective fencing and may at any time require additional fencing if it is deemed necessary to protect either existing native vegetation or the revegetation areas. Any fencing in the floodplain will be of the breakaway type approved by the County Public Works Department and subject to its final approval.

Only construction equipment necessary to accomplish the landscape installation will be allowed in the revegetation areas. Workers' vehicles will be parked outside the riparian open space and all equipment will be removed from the site as soon as its task is completed. No vehicular fluids will be added or changed onsite.

Any use of chemical herbicides for removal of exotics shall adhere to the requirements of the Sweetwater Authority.

Post-construction Protection

After construction is completed and during the 5-year monitoring period, the revegetation sites will remain fenced by temporary 6-foot chain link fence, or 4-stranded barbed wire on T-posts if determined to be appropriate by the revegetation designer, on all sides except those which directly abut existing riparian vegetation. The first post-construction

monitoring report to SDDPLU will certify that this fencing has been completed to the satisfaction of the project revegetation designer. The purpose of the fencing will be to keep all non-maintenance persons and vehicles out of the revegetation areas at all times. In general this will mean that one to three sides of revegetation sites will be fenced. However, in the case of areas which are completely surrounded by existing riparian vegetation in the river basin, fencing will be required which will adequately block access to these sites. Such fencing may be located outside the floodplain if it accomplishes this purpose. If fencing within the floodplain is required perpendicular to the channel, it shall be of the breakaway type recommended by the County Public Works Department and subject to its final approval. Final fencing for these sites will be recommended by the project biologist/ revegetation designer and will be approved by SDDPLU and the San Diego County Public Works Department Flood Control Division. Additional fencing will be added during the monitoring period whenever the biologist/revegetation designer determines that it is necessary to eliminate human, equestrian, or vehicular entry into the project sites.

All temporary fencing will be completely removed from the revegetation sites at the end of the 5-year monitoring period or when the project is given final approval.

1.3.4 Site Grading

Remedial site grading is expected to take place only within the willow woodland revegetation area at Site III. Grading plans for this work shall be prepared by a registered civil engineer and approved by SDDPLU prior to construction. The project revegetation designer and civil engineer will supervise this grading to assure that final grades adequately match the plans and allow for the depths to water table necessary to support the willow woodland vegetation. Final approval of site grading will be made in writing by the revegetation designer to the SDDPLU prior to irrigation installation.

During grading operations, desirable topsoils, as specified by the revegetation designer, will be stockpiled and redistributed to the project after grading is completed. Topsoil stockpiling will be done only in areas approved by the revegetation designer.

Grading work will always remain within the limits of work set by the revegetation designer in the field before the commencement of grading. The contractor will be liable for repair of any damage beyond these limits as per the requirements of the original revegetation plan.

Generally, no fill soils are expected to be used in this project. However, if fill soils are needed, they must be approved by the revegetation designer prior to placement.

All cut soils that are not needed will be removed from the revegetation sites and disposed of offsite in a legally acceptable manner.

Grading equipment will not remain onsite longer than necessary to complete the required work.

1.3.5 General Planting Specifications

Contract Growing and Sources

Arrangements will be made 6-12 months before the expected planting date for all container plant materials and seed required for the revegetation work. An additional 10 percent of the total number of container plants will be grown for replacements and shall be provided by the contractor as needed. A copy of this contract will be submitted to the revegetation designer by the contractor as verification of this matter. Contract growing will be conducted by an experienced native plant nursery or seed company such as, but not limited to, Tree of Life Nursery, San Juan Capistrano, CA.; Mockingbird Nursery, Riverside, CA.; or S & S Seeds, Carpinteria, CA.

Substitutions

The contractor is expected to secure all plant materials well in advance of the expected planting date. No substitutions above 10 percent of any species number specified will be allowed. If the contractor is unable to obtain the proper species specified at the time of planting, commencement of the guarantee period will be delayed until all plants specified are planted. Substitution of plant materials at the time of planting depends solely upon the discretion of the project revegetation designer.

Plant Inspection

All plant materials will be inspected by the revegetation designer and approved as healthy, disease free, and of proper size prior to planting. In addition, the revegetation designer will

approve the final layout of all plant materials in the field prior to planting to assure their correct ecological positioning.

Sources

Whenever possible, it is preferred that the source of all propagules and seed used at the site be secured from wild sources within San Diego County and as close to the revegetation sites as possible. The revegetation designer shall approve all sources of plant materials. The contractor will provide the revegetation designer with information on the sources of all plant and seed materials grown and/or collected for the project, for final approval.

Irrigation System Inspection

Field layout of the irrigation system, shall be based upon final irrigation plans prepared by a registered landscape architect. The installation of this system shall be approved in the field by the revegetation designer and the landscape architect prior to initiating planting.

Container Planting Practices

Container plants will be planted using standard horticultural practices, utilizing a hole twice the diameter of the rootball and leaving the plant crown 2 inches above grade after planting. Oak and sycamore planting holes will be augured to a depth of 6 feet or to the water table, whichever is reached first, and then backfilled with sand to the proper planting depth.

All plants will be thoroughly watered in their pots before planting. Likewise, the soil in all planting holes will be wetted before planting.

A backfill mix containing only native soil mixed with 7 lbs. per cubic yard of Osmocote (18-6-12) slow release fertilizer or equivalent will be used. In addition, container plantings will receive Agriform 21 gram (20-10-5) slow release fertilizer tablets at the rate of one for 1-gallon plantings, and two for 5-gallon plantings. These fertilizer tablets will be placed no deeper than 8 inches from the soil surface.

All sycamores, oaks, and poplar plantings will have 18-inch diameter fabric collars, that are 95 percent impervious to light but permeable to water, placed around their bases following hydroseeding (willows are excluded from this requirement).

No pruning of plant materials will be allowed unless specified by the revegetation designer.

Only oak tree plantings will be staked, unless additional staking is considered necessary for other plants by the revegetation designer at the time of planting. All staking will be conducted with three, 2-inch diameter by 8-foot high wooden stakes located equidistant from the plant in a triangle. Tree ties shall be placed to hold the trunk to the stake at the lowest possible level yet still support the plant. If determined necessary by the revegetation designer, the contractor shall wrap the posts with polyethylene or galvanized hardware cloth mesh to be used as protective caging. A minimum height of 6 feet shall be achieved, to protect the oak trees from deer damage. Staking will be removed as soon as the trees can adequately support themselves. Mesh protection and stakes, if required, will be left in place until oaks reach a minimum of 6 feet in height.

Container Plant Guarantees

All plants determined to be dead or diseased by the revegetation designer will be replaced by the contractor 120 days after installation and then as required by the maintenance program (see Section 2). Unless substitutions are approved by the revegetation designer, the replacement plants shall be of the same size and species as originally planted.

Hydroseeding Specifications

Hydroseeding will be done after the completion of all container plantings. The areas to be hydroseeded will be watered for two weeks prior to seeding or container planting. All weeds growing at the end of two weeks will be sprayed with Rodeo herbicide or equivalent, as determined by a certified Pest Control Advisor. Weeds will then be allowed to die over the course of the next week. Any weeds left alive at the end of the third week will be hand cleared by the contractor prior to hydroseeding. The ground will be thoroughly moist prior to hydroseeding. Planting and hydroseeding will proceed only after the revegetation designer certifies that hydroseed site preparation work has been properly completed.

In areas where different hydroseed mixes will be used, the final limits of the areas to be seeded will be approved by the revegetation designer.

Hydroseed quality will be the best obtainable in the year of application for both purity and germination. No seed shall be more than one year old when applied and shall remain viable.

The amount of seed purchased, its germination rate, and its purity will be provided in writing to the revegetation designer by the contractor for all seed applied. A germination test will be run by the contractor at his own expense for all species used and the results provided to the revegetation designer to substantiate the label listings for percent live seed per pound.

Once seed is in place, the contractor will be responsible for supplying sufficient irrigation to germinate and establish the seed applied. The irrigation system will be checked by the contractor for malfunctioning and/or damage to individual heads every other day for the first three weeks after seeding, and repairs will be made immediately.

Hydroseed Guarantees

The contractor will guarantee a 70 percent coverage rate at 120 days or hydroseed all areas where inadequate seed establishment has taken place. The revegetation designer will determine the necessity for hydroseeding and the areas to be covered.

1.3.6 Monitoring Reports

Progress reports will be made to SDDPLU every two months during the construction period, beginning with a letter certifying that contractor education has been completed and that pre-construction site fencing has taken place. If construction is delayed for any reason, monitoring reports will continue to be filed with SDDPLU at least once every three months. A final report shall be filed at the end of the initial 120-day (4-month) installation maintenance period.

SECTION 2
POST-CONSTRUCTION MAINTENANCE

2.1 TIME FRAME

Once the revegetation designer certifies that revegetation plantings have been completed, a 3- to 5-year maintenance and monitoring period will begin, assuring project success. All revegetation areas subject to 404 or 1603 permitting requirements will be monitored for the full 5 years. All other areas which pertain only to the county 15-acre requirement (Condition 11 of the specific plan) shall be maintained for the minimum required period of 3 years. This period may be extended upon recommendation of the project revegetation designer or SDDPLU if it is concluded that the project did not meet the goals set forth in the performance standards section of this plan. The overall maintenance period is thus divided into an initial 120-day installation-maintenance period, as described in Section 3, and an additional 5 years of maintenance.

2.2 RESPONSIBILITIES

2.2.1 Owner

The owner will be responsible for hiring both a qualified revegetation designer and a landscape contractor for all phases of project installation, maintenance, and monitoring. The owner may, with sole discretion, replace any of these parties. If the revegetation designer is replaced, the owner must notify the SDDPLU of the new designer.

2.2.2 Revegetation Designer

Overall supervision of the maintenance contractor will be the responsibility of the revegetation designer. The revegetation designer will provide the contractor with a written checklist of tasks to be performed after each of his monitoring visits to the site. If the revegetation designer's recommendations call for work beyond the scope of the maintenance contract, the contractor will be paid additional fees for this work once authorized by the owner.

2.2.3 Installation Contractor

The installation contractor will have responsibility for the maintenance of all revegetation areas for 120 days after installation or until final notification is received from the revegetation designer certifying proper completion of all required installation contract maintenance tasks including, but not limited to, dead plant replacement, proper staking, weed clearance, and irrigation system maintenance.

2.2.4 Maintenance Contractor

After 120 days, a maintenance contractor will be hired by the owner for the 5-year monitoring period. The maintenance contract will be let only on a yearly basis and renewed based upon the recommendations of the revegetation designer. At the discretion of the revegetation designer, the maintenance contractor may be changed on a yearly basis if proper maintenance is not performed. The maintenance contractor will be responsible for the maintenance program requirements once the installation contractor's work has been certified as complete. Upon termination of each maintenance contract, the contractor will be responsible for having completed all requests for work specified by the revegetation designer before receiving final payment.

2.3 Contractor Education

The revegetation designer will meet with all maintenance contractors prior to the beginning of their contracts to ensure that they understand the maintenance provisions of the mitigation plan as well as the recommendations for current maintenance procedures. The revegetation designer shall present the contractor with a copy of this document for informational and reference purposes.

2.4 Contractor Guarantees

The contractor will be responsible for the replacement of all plant materials considered dead or diseased by the revegetation designer by the specified replacement dates defined in the success standards (Section 3.0).

2.5 Irrigation System Maintenance

2.5.1 System Repair

The installation contractor shall make general system checks every three days for the first month after installation in order to assure proper system operation, and then at least once every two weeks until the end of the 120-day installation-maintenance period. Thereafter, the maintenance contractor will be responsible for the regular maintenance and repair of all elements of the irrigation system. The maintenance contractor will make general system checks every week for the first month after taking over maintenance to assure that heads are operating properly and that hydroseed coverage is adequate. Thereafter, the maintenance contractor will check system operation at least once a month, except during periods when the system is not in operation, as recommended by the revegetation designer.

2.5.2 System Cycle Documentation

The maintenance contractor will provide the revegetation designer with the cycle start times and the length of each cycle for all valves in the revegetation areas. These times and cycles will be changed as recommended by the revegetation designer. When changes are made, the contractor will provide the revegetation designer with written confirmation of the date and time at which the change was made.

2.5.3 System Removal

The irrigation systems in the revegetation areas are to be removed once the landscape plantings have become established. The revegetation designer will decide how and when irrigation is to be phased out. Upon completion of the irrigation period, all irrigation components which are above grade will be removed by the contractor from the revegetation areas and all valves permanently disconnected.

2.6 Weeding

The installation contractor shall maintain a weed free project during the 120-day installation-maintenance period. Weed removal will require constant diligence by the maintenance contractor. The crucial period for weed control will be the first two years of project establishment. An 18-inch weed free band will be maintained around all container

plantings for the first two years after planting. Thereafter, weed species to be removed and the methods to be used will be specified by the revegetation designer. In general, weed removal will occur by hand or hoe, and no weed whips or herbicides will be permitted. Because of the critical nature of weed control at the beginning of the project, the contractor shall be understood to be held liable for rehydroseeding or replanting if weeds are not removed on a timely basis, thus preventing the establishment of hydroseeded species or container plants. A timely basis shall be understood to be within one week of written recommendation by the revegetation designer or as specified in this document. During the first 120 days, weeds will be removed at least every two weeks. After 120 days, weed removal will take place at least once a month during the first year, once every four months for years 3 and 4, and twice a year during year 5. More frequent monitoring will be performed as necessary or as recommended by the revegetation designer to keep weeds at manageable levels.

Special attention will be given by the contractor to the removal of invasive exotic weed species from all revegetation sites and from all areas within 100 feet of their borders. These species include, but are not limited to, giant cane (Arundo donax), tamarisk (Tamarix spp.), pampas grass (Cortaderia selloana), castor bean (Ricinus communis), and wild tobacco (Nicotiana glauca). Since tamarisk and giant cane are especially difficult to control, herbicide use will be necessary. Such control will consist of 1) cutting the plants to 6" high (only during the active growing season from April to August); 2) treating the cut stems with a 100 percent concentration of "Rodeo" herbicide (to be verified by a certified Pest Control Advisor); and 3) removal of all cut off top growth to an offsite location. Repeat herbicide applications may be necessary on large plants. All small plants are to be removed with their roots, if possible, before herbicide use is attempted. All herbicide use at the project will be carried out under the supervision of the revegetation designer and a licensed Pest Control Advisor. The Sweetwater Authority will have the right to inspect any areas where the use of herbicides is planned at the time of the herbicide application.

2.7 Staking and Caging

Staking of trees will be avoided, if possible, except for oaks, as determined necessary by the revegetation designer. Any stakes used will be removed as soon as a tree can support itself adequately. It is expected that some trees, and especially the oaks, will require staking during the first two years of the project. All stakes will be removed upon completion of the 5-year monitoring period or earlier, or as determined by the revegetation

designer. All stakes removed from trees shall be removed from the revegetation areas by the contractor and disposed of legally.

Caging of trees to protect them from deer damage may be necessary. Therefore oaks will be staked with three posts, such that caging protection may be added at a later date if necessary. If this need becomes evident, caging shall be installed according to the specifications provided in Section 1.0, container planting practices, and as directed by the revegetation designer. The additional costs of this caging will be borne by the owner.

2.8 Dead Plant Replacement

Dead and diseased plants will be flagged in the field by the revegetation designer and a list thereof provided to the maintenance contractor for replacement. Dead and diseased plants will be replaced at 4 and 12 months during the first year after installation. If plants fail to meet the success standards at the end of any given year, plant replacement may be one of the remedial measures recommended by the revegetation designer (see Section 3.0). The cost of replacement plants will ultimately be borne by the owner unless some or all of the responsibility for plant failure is determined to devolve upon the contractor or some other party. All plants will be replaced in kind unless otherwise specified by the revegetation designer.

2.9 Trash and Debris Removal

All human created trash and debris will be removed by the contractor from the revegetation areas at least once every three months throughout the 5-year maintenance period. Care will be taken that these trash removal activities minimize or avoid impacts to plantings in the revegetation areas. All dead limbs and tree fall will be left in the revegetation areas. Weed debris will be removed from the project area and disposed of outside the riparian open space and buffer areas of the development.

2.10 Motorized Vehicle Access

Only one service vehicle will be allowed in any one revegetation area at any time. This vehicle will be no larger than a 6-cylinder pickup truck. Maintenance access to each revegetation site will be limited to the minimum necessary for weed and trash removal. All other vehicles will be parked outside the riparian open space and buffer zone areas of the

project at all times. The project revegetation designer will delineate service access routes and the contractor will be expected to stay within their confines. No vehicular fluids will be changed or added to maintenance vehicles while they are parked in the riparian open space or mitigation areas.

The contractor will immediately notify the revegetation designer if any unauthorized persons, vehicles, or large domestic animals enter the revegetation areas.

2.11 Pest Control

Insects and diseases will be monitored. Biological control will be used whenever possible. Plants that are severely diseased will be removed and replaced to prevent the spread of disease and insects. Pesticides will be largely avoided unless recommended for special problems by the project revegetation designer/horticulturist and acceptable to the Sweetwater Authority. Rodent control, if necessary, will be restricted to trapping or anti-coagulants with no secondary poisoning effect.

2.12 Fertilization

For the first two years after planting, all oak and sycamore container plantings will receive one application of Osmocote (18-6-12) in January of each year. The manufacturer's recommended rates will be applied. The fertilizer will be dug at least 1 inch into the soil within the drip lines of the plants. No other fertilization application will be utilized after the second year unless recommended by the revegetation designer. General broadcast fertilization of understory areas is considered undesirable due to its encouragement of weed growth.

SECTION 3
5-YEAR MONITORING PROGRAM AND SUCCESS STANDARDS

The first purpose of the monitoring program will be to ensure that proper installation, maintenance, and establishment procedures are followed. The second purpose of the monitoring program will be to define performance standards by which to evaluate project progress. The third purpose of the monitoring program will be to recommend remedial measures, if the project does not meet the performance standards, which will bring it back into conformance. Horticultural monitoring will be the primary method for evaluating achievement of the first purpose, and a combination of horticultural and botanical monitoring will be used to evaluate achievement of the second goal. The revegetation designer will recommend remedial measures.

3.1 Time Frame

The monitoring program will begin before construction commences with a preconstruction education session between the contractors involved in project construction and the project revegetation designer. Monitoring will continue for 5 years after completion of installation and until the project is given final approval by the SDDPLU and ACOE. The 5-year period only applies to those revegetation areas which fall under the 404 or 1603 permitting requirements. All other areas shall be monitored for 3 years as stipulated in the county's Specific Plan Condition 11.

3.2 Horticultural Monitoring

The revegetation designer/native plant horticulturist with the qualifications outlined in Section 1.0 will direct the project's horticultural monitoring program. Plantings will be inspected by the revegetation designer on a bi-weekly basis during installation and at least once every 5 weeks during the first 2 years after planting. Thereafter, the revegetation designer will visit the project a minimum of six times a year. However, monitoring visits may be conducted as often as necessary to ensure successful project progress and maintenance.

A written memorandum will be prepared after each monitoring visit, listing problems and recommended remedial measures. These memoranda will be sent to the contractor and owner for implementation. These memoranda will focus on any and all horticultural

problems including weeding, irrigation scheduling, trash removal, pruning, pest control, etc. The revegetation designer will be responsible for all required dead and diseased plant counts and approval of possible substitutions. The revegetation designer will be responsible for recommending all remedial measures to be implemented, and will help determine irrigation scheduling and the timing of the phasing out of the irrigation system.

3.3 Botanical Monitoring

A biologist with the following qualifications will supervise all botanical monitoring: a broad background in vegetation sampling; at least 2 years of local experience in identifying/sampling native vegetation; a good knowledge of the ecological relationships of the vegetative associations onsite; and a minimum of a Bachelor's degree with a focus in botany/ecology.

Botanical monitoring will be conducted concurrently with horticultural monitoring, but will not begin until the end of the second year after installation. Monitoring will be conducted during the active growing season, from May to September. Required reports will be completed within 90 days of the end of each year of monitoring.

At the end of the second year of monitoring, a statistically valid sampling of tree and shrub species will be conducted to establish standards for the 20 percent of the trees that are smallest in height and the 20 percent of the shrubs that are smallest in spread.

In years three and four, vegetation growth and its establishment will be quantitatively assessed through the use of 30-meter belt or line transects placed at the rate of three per acre (for each revegetation habitat type). Transect monitoring will be required for all mitigation areas falling under the 404 or 1603 permitting requirements (estimated to be approximately 8 acres). Data collected from these belt transects will be used to evaluate project performance relative to the success standards (Section 3.0). Data will be collected on groundcover composition and percent of cover. In addition, for the container planted material, annual data will be collected on individual canopy cover and height for all species. This will be used as a means of predicting or measuring achievement of the year three to five height goals and the year five canopy cover goals. Botanical transect monitoring will be repeated in year five, if so recommended by the biological monitor or the county at the end of the fourth year.

3.4 Monitoring Reports

3.4.1 During Installation

Progress reports will be made to SDDPLU every two months during the construction period, beginning with a letter certifying that contractor education has been completed and that pre-construction site fencing has taken place. If construction is delayed for any reason, monitoring reports will continue to be filed with SDDPLU at least once every three months. A final report shall be filed at the end of the 120-day (4 month) period.

3.4.2 After Installation

Monitoring reports will be filed with SDDPLU at 3, 6, 9, 12, 18, 24, 36, 48, and 60 months. Reports will describe project progress, remedial measures recommended, and remedial measures implemented during the reporting period. More detailed reports will be prepared at the end of each year and will include a summary and analysis of the botanical monitoring data collected and an evaluation of project progress relative to the success standards.

Copies of all yearly monitoring reports will be sent to the owner, the county, and all appropriate resource agencies.

3.5 Success Standards and Remedial Measures

3.5.1 Purpose and Basis for Standards

This section defines a set of yearly performance standards for evaluating project progress. These standards will be used to determine when to implement necessary remedial measures to correct problems which arise. These standards are based on Ogden's experience on previous riparian revegetation projects. They are largely derived from the standards currently being used to monitor the First San Diego River Improvement Project (FSDRIP). In addition, standards for understory shrub cover have been included. Initial FSDRIP data have shown a strong relationship between tree height, girth, and canopy cover (ERCE 1989); thus, height alone will be used as a measure of this project's tree growth success. Canopy cover data will also be collected during the botanical monitoring period in order to further corroborate this criterion.

3.5.2 Scope of Remedial Measures

While remedial measures are partially defined, they are also left to the discretion of the horticultural monitor, since it is expected that one approach will not always be the best or most cost effective. Remedial measures will include some or all of the following: additional weeding, fertilization, pest control, replanting, additional irrigation, changes to irrigation system, and species substitution.

3.5.3 Project Success Standards and Recommended Remedial Measures

	Standard	Remedial Measure If Standard Not Met
Year 1		
1.	65% (visual assessment) groundcover	Reseed/Replant Substitutions possible
2.	Establishment of all species	Reseed/Replant Substitutions possible
3.	100% healthy container plantings	Replace with same species/size
Year 2		
1.	65% (visual assessment) groundcover	
2.	All trees growing at an acceptable rate	Smallest 20% of container (as measured by height) trees receive remedial measures
3.	All shrubs growing at an acceptable rate	Smallest 20% of shrubs receive remedial measures
4.	100% survival of tree plantings 80% survival of shrub plantings	Replant
Years 3–5		
1.	65% (visual assessment) groundcover	
2.	Height standards met for all trees	Replant or remedial measures Substitutions possible

Standard				Remedial Measure If Standard Not Met
Years 3–5 (Continued)				
Tree Height Standards[1,2]	YR3	YR4	YR5	
Oaks (5 gal.)	1.0	1.5	1.75	
Oaks (treepot)	0.75	1.0	1.5	
Poplars (1 gal.)	4.9	6.4	7.9	
Sycamores (5 gal.)	1.5	2.0	3.0	
Willows (1 gal.)	2.0	2.7	3.4	
Mule fat and sandbar willow (1 gal.)	1.2	1.5	1.8	
3. 90% survival of tree plantings[3] 80% survival of shrub plantings				Replant
4. Irrigation will gradually be withdrawn from the revegetated areas during years three and four. For the project to be considered successful, plants must survive through one full dry season without supplemental irrigation. Thus, no matter when the monitoring period begins, final project evaluation will not be made until the first March after irrigation has been discontinued.				

1 All heights given in meters.

2 These standards are derived from projections of first and second year FSDRIP data (ERCE 1988, 1989). They may be modified if they prove unworkable because of different site conditions at Rancho San Diego.

3 At the discretion of the project monitor, dead container plantings can be mitigated by naturally invading seedlings if such seedlings are within 5 feet of the original plantings and of similar species or habitat value.

3.6 Modification of Monitoring Period

The monitoring period is specified to last 5 years after installation for all areas subject to 404 or 1603 mitigation requirements and 3 years for all other revegetation areas. The county and/or the resource agencies (under each project's 1603 or 404 permits granted) must approve any proposed early termination of monitoring if recommended by the monitoring biologist in a year-end report. Likewise, if, at the end of 3 or 5 years, any of the revegetated areas fail to meet the project's final success standards, then the monitoring and maintenance period will be extended one full additional year and a specific set of remedial measures (approved by SDDPLU) will be implemented. Only areas which fail to meet the success standards will require additional work, i.e., not all of the areas originally revegetated. This process will continue until all standards are met or until SDDPLU determines that other mitigating measures are appropriate.

APPENDIX D

NURSERY QUESTIONNAIRE AND RESULTS

ALAMEDA CREEK
NURSERY QUESTIONNAIRE
SUMMARY

This summary was prepared from the six responses we received from the questionnaire that was sent to nursery leaseholders along Alameda Creek. It assumes that the information provided is accurate. We have not received responses from two growers as of December 17, 1992.

Irrigation Practices

132 acres are reported to be under drip irrigation, 26 acres are under conventional sprinkler irrigation, 33 acres are hand watered and 3 acres receive one annual furrow irrigation. They state that they have a total of 189 acres in production. Some of the acreage has more than one type of irrigation delivery system, which explains why the acreage numbers do not equate.

More than half of the growers did not know or did not provide their annual water consumption.

Assuming an annual evapotranspiration rate of 49.9 inches, which may or may not be accurate (the historical average of San Jose and Davis), one nursery is applying about 120 percent and the other is applying about 216 percent of assumed annual evapotranspiration. The nursery with the higher consumption may be applying excess water.

Most growers said that they irrigate based on plant need, the weather, visual inspection of the stock and their experience.

They grow everything from bedding plants on up to boxed trees and there is one three acre orchard among the responses.

None claim to have any irrigation runoff and most state that storm runoff does not flow to the creek.

Fertilizer and Pesticide Use

All operations stated that they fertilize their crops, incorporating fertilizer into the soil and most inject fertilizer with their irrigation water. They use a wide variety of fertilizer products.

Fertilizer is applied with every irrigation at most locations.

All growers seem to know how much fertilizer they apply, though not all of them provided total consumption figures.

The following pesticides (by trade name) are reported to be used on a regular basis:

Nursery: H C Nursery
Address: P.O. Box 50
Lease No.: Sunol, Ca 94586

Questions for Nursery Properties Leased along Alameda Creek

The San Francisco Water District is conducting a survey of activities in the district's watersheds. Please take a few minutes to fill out this questionnaire. Your cooperation is appreciated.

Irrigation Practices

1. How do you apply water to your nursery stock? (Check all that apply)
   Drip System___ Spray System ✓ Hand Water ✓
   Acreage _____ Acreage 8 Acreage 8

2.A. Who determines how often to water your stock? (Please list them by name and job title) Tim Schanz - grower on site

B. How do they decide when to water? As the plants need water by visual inspection not set days & time

C. How do they determine how much water to apply? By the size of Con

4. A. What is your annual water use? ?

B. How many acres do you have in production? 8 acres

C. What type of material do you sell? (Check all that apply)
   Flats and Liners ✓ Container stock ___ Boxed trees ___
   Bedding plants

5. What actions do you take to conserve water in your operation? 1. water only as. 2. Hand water as needed 3. inspect irrigation sy

6. Do you monitor the quantity of irrigation runoff? Yes ✓ No ___ .rotate
   Does runoff (including rainwater) go towards the creek when it leaves the site?
   Yes ✓ No ___ stop by barrier

7. Do you intercept or reuse any of the runoff before it leaves the site? (Explain)

Fertilizer and Pesticide Use

8. How do you apply fertilizer to your stock and what fertilizers do you use?
Mixed in soil at time of planting.
Fertilizer Blend by Romeo Fertilizer Company
injected in water special Blend 200 ppm

9. How often do you fertilize your stock and what is your annual use?
200 ppm in 3 out of 4 watering
use 4-5 tons annually

10. Do you have a regular pest control program?
Yes ✓ No ___

11. Which chemicals do you apply on a regular basis? None as need if insect population are observed

12. What other chemicals do you apply on occasion?
Subdue, chipco 26019, Roundup, D-9, Diazinon, orthene Avid, Mavrik, Bursban,

13. Is there any soil erosion at your nursery, or on slopes immediately adjacent to your nursery? If so, where does the soil go? No.

Thank you for taking the time to complete this survey.

Nursery: NAKA
Address: 6825 - CALAVERAS Rd. SUNOL CA. 94586

Lease No.:

Questions for Nursery Properties Leased along Alameda Creek

The San Francisco Water District is conducting a survey of activities in the district's watersheds. Please take a few minutes to fill out this questionnaire. Your cooperation is appreciated.

Irrigation Practices

1. How do you apply water to your nursery stock? (Check all that apply)
   Drip System ~~LAC~~ Spray System ____ Hand Water ✓
   Acreage 2-AC Acreage _____ Acreage 25

2. A. Who determines how often to water your stock? (Please list them by name and job title) Foreman - Raul Mariscal

   B. How do they decide when to water? when the plants start looking dry. depend on the weather.

   C. How do they determine how much water to apply?
   depend of size container.

4. A. What is your annual water use? _____

   B. How many acres do you have in production? 20 acres

   C. What type of material do you sell? (Check all that apply)
   Flats and Liners____ Container stock X Boxed trees X

5. What actions do you take to conserve water in your operation? drip system and watering by hand

6. Do you monitor the quantity of irrigation runoff? Yes ____ No ____
   Does runoff (including rainwater) go towards the creek when it leaves the site?
   Yes ____ No X

7. Do you intercept or reuse any of the runoff before it leaves the site? (Explain)

   NO

AKA NURSERY, INC.
36501 NILES BLVD.
P. O. BOX 2008
FREMONT, CA 94536

Fertilizer and Pesticide Use

8. How do you apply fertilizer to your stock and what fertilizers do you use?

HAND FERTILIZER

20-5-11- 20-5-5 19-3-10
18-6-12 19-6-12 0-10-10
17-7-12 34-0-0- 330-IRON

9. How often do you fertilize your stock and what is your annual use?

3- FOR-MONTH

4 TON of fertilize.

10. Do you have a regular pest control program?
Yes ✓ No ___

11. Which chemicals do you apply on a regular basis?

HERBICIDES. CHIPCO RONTAR.
SIMAZINE 80W
ROUNDUP

12. What other chemicals do you apply on occasion?

FUNGACIDE BENLATE
AGRI-STREP

13. Is there any soil erosion at your nursery, or on slopes immediately adjacent to your nursery? If so, where does the soil go?

Thank you for taking the time to complete this survey.

NAKA NURSERY, INC.
36501 NILES BLVD.
P. O. BOX 2008
FREMONT, CA 94536

Nursery:
Address:

Lease No.:

Questions for Nursery Properties Leased along Alameda Creek

The San Francisco Water District is conducting a survey of activities in the district's watersheds. Please take a few minutes to fill out this questionnaire. Your cooperation is appreciated.

Irrigation Practices

1. How do you apply water to your nursery stock? (Check all that apply)
   Drip System____ Spray System ____ Hand Water____ Reclaimed Water
   Acreage _____ Acreage _____ Acreage _____ 3 acres

2.A. Who determines how often to water your stock? (Please list them by name and job title) Nigata Farms (Tashi Nigata)

B. How do they decide when to water?

Time application (Eyeball gauge ...

C. How do they determine how much water to apply?

I don't know

4. A. What is your annual water use? I don't know

B. How many acres do you have in production? 3 acres

C. What type of material do you sell? (Check all that apply)
   Flats and Liners____ Container stock ____ Boxed trees ____ Does not apply

5. What actions do you take to conserve water in your operation?

6. Do you monitor the quantity of irrigation runoff? Yes X No ____
   Does runoff (including rainwater) go towards the creek when it leaves the site?
   Yes ____ No X

7. Do you intercept or reuse any of the runoff before it leaves the site? (Explain)

Fertilizer and Pesticide Use

8. How do you apply fertilizer to your stock and what fertilizers do you use?

In Compete in Last - (15-15-15)

9. How often do you fertilize your stock and what is your annual use?

3 acres — 640 LBS year

10. Do you have a regular pest control program?
Yes ___ No X

11. Which chemicals do you apply on a regular basis?

None

12. What other chemicals do you apply on occasion?

Round-up

13. Is there any soil erosion at your nursery, or on slopes immediately adjacent to your nursery? If so, where does the soil go?

No

Thank you for taking the time to complete this survey.

Ingalls Farms

Lucille Ingalls

Nursery: Valley Crest Tree Company
Address: 9501 Calaveras Road, Sunol Ca.

Lease No.:

Questions for Nursery Properties Leased along Alameda Creek

The San Francisco Water District is conducting a survey of activities in the district's watersheds. Please take a few minutes to fill out this questionnaire. Your cooperation is appreciated.

Irrigation Practices

1. How do you apply water to your nursery stock? (Check all that apply)
   Drip System X Spray System ____ Hand Water____
   Acreage 90 Acreage _____ Acreage _____

2.A. Who determines how often to water your stock? (Please list them by name and job title) emory Chow Production Manager

B. How do they decide when to water? we have established watering patterns and ~~cyfole~~ cycles which correspond to the time of year and weather.

C. How do they determine how much water to apply?
irrigation is timed and drip emitters are "sized" for each crop.

4. A. What is your annual water use? _____

B. How many acres do you have in production? 90 acres

C. What type of material do you sell? (Check all that apply)
Flats and Liners____ Container stock X Boxed trees X

5. What actions do you take to conserve water in your operation?
all plant material is on drip irrigation

6. Do you monitor the quantity of irrigation runoff? Yes ✓ No ____
Does runoff (including rainwater) go towards the creek when it leaves the site?
Yes (X) No X no runoff

7. Do you intercept or reuse any of the runoff before it leaves the site? (Explain) No.

① no runoff occurs during normal operations

② during rain periods water from across Calaveras road enters through culverts and is directed across toward the creek

Fertilizer and Pesticide Use

8. How do you apply fertilizer to your stock and what fertilizers do you use?
fertilizer is liquid injected into the water at the time of irrigation
We use Nitrogen, Potassium, Phosphorus and trace minerals winter Sept/15 16-10-
summer 24-5
april/aug

9. How often do you fertilize your stock and what is your annual use?
daily during the growing season approx 80tons annually
(see winter summer notes in #8)

10. Do you have a regular pest control program?
Yes X No ____

11. Which chemicals do you apply on a regular basis?
Orthene, subdue, round-up, bayleton, daconil
diazanon, malathion

12. What other chemicals do you apply on occasion?
dursban, sevin, lindane, volk oil, maverick, triforine

13. Is there any soil erosion at your nursery, or on slopes immediately adjacent to your nursery? If so, where does the soil go?
No erosion noticed.

Thank you for taking the time to complete this survey.

Nursery: Dell's Ivy Acres Nursery.
Address:

Lease No.:

Questions for Nursery Properties Leased along Alameda Creek

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Irrigation Practices

1. How do you apply water to your nursery stock? (Check all that apply)
   Drip System____ Spray System ✓ Hand Water____
   Acreage _____ Acreage 3 Acreage _____

2.A. Who determines how often to water your stock? (Please list them by name and job title) Frank Dell owner.
Jini Dell Manager.

B. How do they decide when to water?
Only when needed.

C. How do they determine how much water to apply?
(20 years experience.) Soil, Plant, Heat, Cold, Shade, Et

4. A. What is your annual water use? less than 5 acres Feet.

B. How many acres do you have in production? 3

C. What type of material do you sell? (Check all that apply)
Flats and Liners ✓ Container stock ____ Boxed trees ____

5. What actions do you take to conserve water in your operation?
New Heads. New Use of Plants. That need. Water.
New Sprinkler
6. Do you monitor the quantity of irrigation runoff? Yes ✓ No ____
Does runoff (including rainwater) go towards the creek when it leaves the site?
Yes ____ No ✓ Not to Creek.

7. Do you intercept or reuse any of the runoff before it leaves the site? (Explain)

All water. Percolate on property before reaching any adjacent property.

Fertilizer and Pesticide Use

8. How do you apply fertilizer to your stock and what fertilizers do you use?

INJECTOR SYSTEM.
LIQUID (20-20-20) W.P.
AN 20 BULK.
0-0-12 BULK.

9. How often do you fertilize your stock and what is your annual use?

CONSTANT FEED SOME AREAS AT 160 P.P.M. N.
WHEN NEEDED ON A SPOT BASIS. 90 P.P.M. K.

10. Do you have a regular pest control program?
Yes ___ No ✓ SALMAN ONLY WHEN NEEDED

11. Which chemicals do you apply on a regular basis?

NONE.

12. What other chemicals do you apply on occasion?

26019.
DURSBAN.
FUNGO FLO.

13. Is there any soil erosion at your nursery, or on slopes immediately adjacent to your nursery? If so, where does the soil go? NO.

Thank you for taking the time to complete this survey.

Nursery: Pacific Nurseries of California, Inc.
Address: 2099 Hillside Blvd
Colma, CA 94014
Lease No.: 3666, 3303, 3198, 3199, 3428, 3371, 3467, 3667.

Questions for Nursery Properties Leased along Alameda Creek

The San Francisco Water District is conducting a survey of activities in the district's watersheds. Please take a few minutes to fill out this questionnaire. Your cooperation is appreciated.

Irrigation Practices

1. How do you apply water to your nursery stock? (Check all that apply)
   Drip System X Spray System X Hand Water X
   Acreage 40 Acreage 15 Acreage Not Applicable: occasional spot watering.

2. A. Who determines how often to water your stock? (Please list them by name and job title) Matt Pulliam - Pacific Nurseries, Sunol Manager
   Arthur Boada - Production Manager
   Miguel Anaya - Foreman

   B. How do they decide when to water?
   All irrigation systems are on timer control; settings determined by season and plant requirements.

   C. How do they determine how much water to apply?
   Quantity of water applied is determined by container size, plant requirements, weather conditions and whether water is applied by drip or rain-bird

4. A. What is your annual water use? 165 Acre Feet

   B. How many acres do you have in production? Aproximately 55

   C. What type of material do you sell? (Check all that apply)
   Flats and Liners ___ Container stock X Boxed trees X

5. What actions do you take to conserve water in your operation? Since 1987 we have converted 12 acres of 15 gal stock and 6.5 acres of 5 gal stock to drip irrigation. We are planning to convert the remaining 4

6. Do you monitor the quantity of irrigation runoff? Yes ___ No X acres of 5 gal
   Does runoff (including rainwater) go towards the creek when it leaves the site? drip.
   Yes ___ No X *see page

7. Do you intercept or reuse any of the runoff before it leaves the site? (Explain) Yes. We have two catch-ponds at the west end of nursery which intercept runo: We do not reuse this runoff at this time. We have a 15 acre pa: which is composed of 95% 1 gal stock. Because the mechanics of drip system are not feasible in this area we are looking into a system which reuses water from the holding ponds. We are confe: with Monterey Bay Nursery about their system for reuse.

Fertilizer and Pesticide Use

8. How do you apply fertilizer to your stock and what fertilizers do you use?
   Fertilizer is applied via injector system. We use Nitrogen and Potassium.

9. How often do you fertilize your stock and what is your annual use?
   Fertilizer is applied with every irragation via injector system. Annual liquid fertilizer use: Nitrogen - 14,514 g; Potassium 9,019 g.

10. Do you have a regular pest control program?
    Yes _X_ No ___

11. Which chemicals do you apply on a regular basis?
    Orthene, Diazinon, Bayleton, Subdue.

12. What other chemicals do you apply on occasion?
    Plantax, Dursban, Triforine, Agristrip
    Herbicide: Scott OH II, Surflan, Expedite, Round-up.

13. Is there any soil erosion at your nursery, or on slopes immediately adjacent to your nursery? If so, where does the soil go?
    There is no measurable soil erosion in the nursery or on adjacent slopes.

Thank you for taking the time to complete this survey.

* #5 cont'd
In 1987 our daily use was approximately 300,000 gal daily. Even though we have added 1000 each 24" box trees, 23,680 15 gal and 16,000 5 gal, we have still reduced consumtion to 150,000 daily. After the conversion to drip in the remaining 5 gal section, we can further reduce our water use.

Exec V.P.

Nursery: JEFF ALLEN NURSERY
Address: NAKD NSY GROWING GRASSES -
Lease No.: ?

Questions for Nursery Properties Leased along Alameda Creek

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Irrigation Practices

1. How do you apply water to your nursery stock? (Check all that apply)
   Drip System____ Spray System ____ Hand Water ✓
   Acreage _____ Acreage _____ Acreage _____

2.A. Who determines how often to water your stock? (Please list them by name and job title) JEFF ALLEN - OWNER

B. How do they decide when to water?
CHECK SOIL MOISTURE

C. How do they determine how much water to apply?
CHECK SOIL MOISTURE AFTER IRRIGATION. ONCE SOIL IS

4. A. What is your annual water use: WE DON'T REALLY KNOW, MY GUESS 1-1.5 M GA

B. How many acres do you have in production? 2 acres

C. What type of material do you sell? (Check all that apply)
   Flats and Liners____ Container stock X Boxed trees ____

5. What actions do you take to conserve water in your operation? ALSO WE
WE ONLY WATER PLANTS WHEN THEY NEED IT. GROW MOSTLY NATIVES AND DROUGHT TOLERANT ORNAMENTALS A
6. Do you monitor the quantity of irrigation runoff? Yes ____ No X DERENNIA
   Does runoff (including rainwater) go towards the creek when it leaves the site?
   Yes ____ No X

7. Do you intercept or reuse any of the runoff before it leaves the site? (Explain)
NO

Fertilizer and Pesticide Use

8. How do you apply fertilizer to your stock and what fertilizers do you use?

PRE-MIX & TOP DRESS
(TRACTOR) (HAND)

9. How often do you fertilize your stock and what is your annual use? FERTILIZATION VARIES, SOME PLANTS NEED ADDITIONAL FERTILIZER WHILE OTHERS PREFER LOW APPLICATIONS (NO ADDITIONAL). 5-6 TONS

10. Do you have a regular pest control program?
Yes X No ___ WE PRACTICE BIOLOGICAL CONTROL AND GROW A DIVERSITY OF PLANTS WHICH REDUCES INFESTATION SIGNIFICANTLY.

11. Which chemicals do you apply on a regular basis?

NONE.

12. What other chemicals do you apply on occasion?

METALDEHYDE FOR SNAIL CONTROL

13. Is there any soil erosion at your nursery, or on slopes immediately adjacent to your nursery? If so, where does the soil go?

NO

Thank you for taking the time to complete this survey.

APPENDIX E

ALAMEDA CREEK WATERSHED STUDY, FISHERY RESTORATION FEASIBILITY EVALUATION AND PRELIMINARY RESTORATION PLAN NOVEMBER 1993

Alameda Creek Watershed Study
Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan

Final Report
November 1993

BioSystems

ALAMEDA CREEK WATERSHED STUDY

FISHERY RESTORATION FEASIBILITY EVALUATION AND PRELIMINARY RESTORATION PLAN

FINAL REPORT

Prepared for:

Bookman-Edmonston Engineering, Inc.
3100 Zinfandel Drive, Suite 170
Rancho Cordova, CA 95670

and

City and County of San Francisco
Public Utilities Commission
San Francisco Water Department
P.O. Box 730
1000 El Camino Real
Millbrae, California 94030

Prepared by:

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Jung Yoon

BioSystems Analysis, Inc.
3152 Paradise Drive
Tiburon, California 94920

November 1993

J 728

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SUMMARY

Flow in Calaveras and Alameda Creeks has been regulated since 1916 when construction of Calaveras Dam was completed. Normal hydrology may have been altered as early as 1913 when construction of the dam began. In an attempt to improve water resource utilization, the San Francisco Water Department (SFWD) is exploring the possibility of increasing releases from Calaveras Reservoir for recapture and consumptive use downstream. With increased flows, Calaveras and Alameda Creeks may again have the potential to support trout populations. BioSystems Analysis, Inc. was contracted by Bookman-Edmonston Engineering, Inc. to evaluate the feasibility of establishing a rainbow trout population in Calaveras and Alameda Creeks below Calaveras Dam for SFWD.

The primary focus of our study was to identify any conditions that could preclude establishment of a trout population. However, if our study indicated that a rainbow trout population could be established in Calaveras and Alameda Creeks below Calaveras Dam, our next objective was to determine the best management policy for the creeks. Our work was part of a larger study that also examined the technical feasibility of recovering Calaveras Reservoir water releases downstream in the Sunol Valley through a conjunctive use program.

A review of trout populations in other regional streams indicates water quality in Calaveras Reservoir is of critical importance to development of a rainbow trout population in Alameda Creek. Reservoir releases must be cold to support trout populations. During the summer, water released from the reservoir warms as it moves downstream, so the release temperature must be as cold as possible during this time. Reservoir releases must also be free of substances harmful to fish and other aquatic life.

To evaluate the suitability of Calaveras Reservoir release quality, experimental water releases from Calaveras Reservoir were made between 28 September and 1 October 1992. Habitat conditions were recorded in two experimental reaches, water quality data were collected near the release point and at two downstream locations, and stream temperature and meteorological conditions were monitored during the late summer and fall, including the experimental flow release period. Stream temperatures and meteorological data were used to calibrate the SNTEMP model for predicting stream temperatures.

No conditions in Alameda Creek or Calaveras Reservoir were identified in the summer of 1992 that would preclude development of fish population downstream of Calaveras Dam. The major factor potentially limiting trout populations was high water temperature resulting from low instream flow during the summer months. The extent of suitable trout habitat downstream from Calaveras Dam will depend on the level of flow from the reservoir and thermal conditions within the reservoir. If reservoir stratification and storage levels are consistent with historic operation, our study indicates that suitable conditions (average daily water temperature of 20°C [68°F] or less) can be maintained downstream to the Sunol Regional Park throughout the summer at a flow of 7 cubic feet per second (cfs), in all but a few dry years. Suitable conditions for native non-game fishes continue to the Sunol Valley Filtration Plant. In these few years, Calaveras Reservoir is likely to be too low to have sufficient cold water storage. This flow rate is based on a worst case scenario (i.e., hottest meteorological conditions with warmest release condition).

Potential water quality problems involving low dissolved oxygen, high concentrations of hydrogen sulfide, high turbidity, unsuitable pH, and high levels of dissolved metals were not encountered during experimental flow releases. Reservoir levels during the data collection period were low because of several years of construction activity and below normal rainfall, so water quality conditions should have been at or near the worst levels possible.

We observed suitable micro-habitat and macro-habitat conditions for rainbow trout at all flow levels. Although this study was not specifically designed to determine the optimum level of flow for rainbow trout, observations indicated that suitable conditions for adults and for spawning were observed at 20 cfs. Habitat improvement projects to create deeper pools and increase instream cover may increase the amount of adult habitat at lower flow levels. Conditions for fry and juvenile life-stages appeared reasonably good at all flow levels observed.

To identify the preferred management plan for Alameda Creek, the SFWD held a meeting on 3 August, 1993 with representatives from the SFWD, California Department of Fish and Game, California Trout, and University of California at Davis to solicit their input. We presented five management alternatives for Alameda Creek at the meeting which were discussed in detail and refined. Four alternatives recommend that the rainbow trout fishery be restored. These alternatives differ in the degree of exploitation by anglers of the trout fishery and the relative impact of each plan on the native fish community. The fifth alternative provides for protection and enhancement of the native fish community without an emphasis on rainbow trout.

After careful deliberation, Alternative 4 (Protection and Enhancement of Native Rainbow Trout and Non-Game Fishes) was selected as the preferred alternative by all parties. Although this alternative does not maximize habitat conditions for either rainbow trout or native non-game fishes, it does provide a balance between the requirements of these fisheries. The plan provides for a limited wild trout recreational fishery, if the population is monitored closely. Biodiversity in Alameda Creek is enhanced under this alternative with the upper half of the study reach (Calaveras Dam to Sunol Regional Park) managed for trout and other native cold-water species and the lower reach (Sunol Regional Park to the filter plant) managed for native warmwater non-game fishes.

Based on our studies, we recommended the following steps as the basis for the native fish restoration plan:

- Maintain Calaveras Reservoir stratification conditions within present levels.
- Maintain 30 thousand acre-feet (TAF) in storage in Calaveras Reservoir at the end of October to ensure sufficient cold water for downstream releases.
- Provide winter trout habitat from 1 November through 31 January by maintaining a 5-day running average flow of 5 cfs immediately below the confluence of Alameda Creek and Calaeras Creek with a minimum mean daily flow of not less than 4.5 cfs.
- Provide habitat suitable for rainbow trout spawning from 1 February through 31 March by maintaining a 5-day running average flow of 20 cfs immediately below the confluence of Alameda Creek and Calaveras Creek with a minimum mean daily flow of not less than 18 cfs. Ramping up to this level early in the period should be acceptable.

- Provide suitable temperature conditions for trout downstream from Calaveras Dam to the Sunol Regional Park from 1 April to 31 October by maintaining a 5-day running average flow of 7 cfs immediately below the confluence of Alameda Creek and Calaveras Creek with a minimum mean daily flow of not less than 6.3 cfs.

- Monitor downstream temperatures to verify model results.

- Evaluate the need for periodic flushing flows; historic records indicate that there may already be adequate flows.

This study has identified instream flows, especially during summer, as the critical factor limiting trout and native non-game fish populations in Alameda Creek. Therefore, the restoration plan, at this stage, focuses on supplying flows to provide the basic habitat conditions necessary to enhance native fish populations in the stream. The precise level of flow for optimizing habitat conditions would require a more detailed study, such as an IFIM evaluation. The study also identified secondary factors that may limit the native fish population after they becomes established. These include lack of deep-water habitat for adults, some degradation of the riparian community because of grazing in certain areas, and excessive growth of cattails in some areas as a result of low summer streamflows. If instream flows are provided and native fish population become established, careful monitoring should be used to identify areas where further restoration efforts may be worthwhile.

1.0 INTRODUCTION

Many tributaries of San Francisco Bay, including Alameda Creek, once supported native populations of rainbow trout (*Oncorhynchus mykiss*) as well as its anadromous form, steelhead (Skinner 1962). Due to rapid urban development, loss of riparian habitat, water diversion, introduction of non-native species, and creation of migration barriers, many of these trout populations have all but disappeared. Recent droughts also have contributed to their demise. While some trout habitat is still available in many of these streams, a lack of water hinders migration and spawning attempts by this species and limits instream habitat, even in streams with no barriers.

For many of the same reasons, populations of non-game native fishes have also declined. In the past, resource agencies have, in some areas, made concerted efforts to eliminate native non-game fishes (i.e., poisoning, selective removal) to decrease competition and predation on game fishes. The approach of resource agencies to the management of native non-game fishes, however, has changed considerably in recent years. Maintaining biodiversity has now become an important objective of resource management (J. Turner, CDFG -Environmental Services, pers. comm.). This change in philosophy has resulted in a higher value being placed on all native fishes, regardless of their sport value.

Flows in Calaveras and Alameda Creeks have been regulated since 1916 when construction of Calaveras Dam was completed. In an attempt to improve water resource utilization, the SFWD is exploring the possibility of increasing releases from Calaveras Reservoir for recapture and consumptive use downstream. With increased flows, Calaveras and Alameda Creeks may have the potential to once again support trout populations. Increased flow could also be used to improve habitat conditions for the current assemblage of native non-game fishes residing in the stream.

Rainbow trout are typically found in cool, clear, well-oxygenated streams with balanced amounts of riffle and pool habitat. Optimum temperatures for rainbow trout range from 13° to 21°C (55°-70°F), depending on the life stage present (Moyle 1976). Stream depth, velocity, and cover are also important determinants of habitat suitability for trout; all of these factors are related to stream flow and channel conditions. Rainbow trout become sexually mature in their second or third year and spawn in the spring. Appropriate spawning habitat consists of gravel substrate with higher velocity flow, such as found in riffles, runs and the tails of pools. Eggs hatch in three to four weeks and, depending on temperature conditions, fry emergence typically occurs two to three weeks later. At this point, quiet backwaters and pools become important rearing habitats for the young rainbow trout. Riparian vegetation is essential for stabilizing banks, providing fish cover, and maintaining cool instream temperatures. Insects and other small animals associated with riparian vegetation can be an important source of food for trout.

In general, less information is known about the habitat requirements of non-game native fishes. Therefore, the effect of increased flow on this fish community is harder to assess. In general,

the non-game native fish currently residing in Alameda Creek prefer warmer temperatures than trout and are better adapted at withstanding large flow fluctuations than most introduced species.

Because the Calaveras and Alameda Creek watersheds historically supported trout and are relatively undisturbed in the upper reaches, they are appropriate candidates for trout restoration studies. Although dams, quarrying activities, and other human influences have permanently altered Alameda and Calaveras Creeks, the major factor limiting trout populations may be a lack of instream flows. Provision of instream flow between Calaveras Reservoir and a recovery point in Sunol Valley may allow for restoration of a trout population.

The primary purpose of our study was to evaluate the feasibility of establishing a rainbow trout population in Calaveras and Alameda Creeks below Calaveras Dam. This was part of a larger study that also examined the technical feasibility of recovering Calaveras Reservoir releases downstream in the Sunol Valley through a conjunctive use program. We conducted a literature and data review to evaluate historical fish populations and conditions in the watershed, as well as determine the success of similar stream restoration projects. In addition, we conducted field surveys to assess trout habitat conditions in the creek under different levels of flow. Instream habitat, water temperature, and water quality were the main factors considered. Using this information, we evaluated the feasibility of restoring a rainbow trout population in the creek and investigated possible directions for stream restoration.

After determining whether or not a rainbow trout population could be established in Calaveras and Alameda Creeks below Calaveras Dam, our next objective was to determine the best management policy for the creeks. To accomplish this goal, we met with representatives from SFWD, California Department of Fish and Game, California Trout, and University of California-Davis to refine the potential management options identified for the creeks and, secondly, develop a preferred management plan that could be agreed to by all interested parties.

2.0 BACKGROUND

2.1 HISTORICAL FISH POPULATIONS

One of the earliest reports of fish populations in the Alameda Creek watershed documented the occurrence of six native species including California roach, hitch, Sacramento squawfish, Sacramento sucker, tule perch and prickly sculpin (Snyder 1905). Aceituno et al. (1976) reviewed other early collections and conclude that at least five and possibly six additional species were native to the watershed. These include rainbow trout, Sacramento blackfish, threespine stickleback, riffle sculpin, and Pacific lamprey. Sacramento perch have been collected in Alameda Creek but their presence is believed to be the result of an introduction to Calaveras Reservoir (Aceituno et al. 1976).

Follett (1974) reported observing one small trout immediately below the dam in Niles Canyon in 1927 and collecting juvenile rainbow trout in Stonybrook Canyon in 1955 and at pools opposite Niles nursery in 1957. Rainbow trout have been documented above Calaveras Reservoir on several occasions between 1905 and more recent times (Leidy 1984). Snyder (1905) reported rainbow trout from Arroyo Hondo, Isabel, and Smith Creeks. Collections are reported from Isabel Creek in June of 1975 (Leidy 1984); in Isabel Creek, Smith Creek, and Arroyo Hondo (Scoppettone and Smith 1978); and from Smith and Isabel Creeks in August 1981 (Leidy 1984). This is probably a landlocked population derived from a coastal steelhead stock that was isolated in the upper part of the drainage by natural processes or by the construction of Calaveras Dam between 1916 and 1925. Similar populations exist in San Leandro Reservoir tributaries and in San Pablo Creek above San Pablo Reservoir (Needham and Gard 1959).

Rainbow trout have also been collected below Calaveras Dam. Scoppettone and Smith (1978) report collections in Alameda Creek at milepost 5, Ohlone Camp Road, and at 0.5 km (0.3 mi) upstream from the junction with Calaveras Creek (Leidy 1984). Gray (1988) documented the occurrence of young-of-year rainbow trout in Alameda Creek just upstream of its confluence with Calaveras Creek in 1983 and again in 1987. Recent field studies by the Environmental Protection Agency (EPA) have confirmed the presence of healthy resident trout populations in two areas of the Alameda Creek watershed: one immediately upstream of the confluence of Alameda and Calaveras Creeks in the Little Yosemite area and one above the Alameda Creek diversion dam (R. Leidy, EPA Wetlands Division, pers. comm.). These trout are probably the result of spawning by resident stream fish, since there are several barriers to migration of steelhead in Niles Canyon and below.

The California Department of Fish and Game (CDFG) maintains that historically Alameda Creek was a steelhead stream but that, as a result of water development and urbanization within the drainage and loss or degradation of steelhead spawning and rearing habitat, self-sustaining steelhead were likely extirpated within the drainage by the late 1950s (CDFG 1975). No records of spawning run counts or estimates of the steelhead population size in Alameda Creek were

found in CDFG files in Los Gatos. CDFG now stocks Alameda Creek in Niles Canyon with catchable rainbow trout.

2.2 HYDROLOGIC AND WATER QUALITY CONDITIONS

Hydrologic conditions within the Calaveras Creek and Alameda Creek watersheds have defined habitat conditions for trout and native non-game species in the past and will ultimately determine the amount of water available for improving habitat conditions for fish below Calaveras Dam. The seasonal hydrologic patterns of Alameda Creek are typical of Central California coastal streams. The U.S Geological Survey (USGS) collected streamflow data at Arroyo Hondo (the primary source of inflow to Calaveras Reservoir) from 1969 to 1981. Streamflows peak in January, February, and March and decline to extremely low levels during the summer months (June-October) (Figure 2-1). Historically, flow below the present site of Calaveras Reservoir would have included runoff and some seepage from the valley now containing the reservoir, as well as flow from Alameda Creek which joins the Calaveras tributary a short distance below Calaveras Dam. Flood flows in Alameda Creek are presently diverted to Calaveras Reservoir through the Alameda Creek diversion.

Calaveras Reservoir storage data from 1963 to 1990 show that the maximum storage level (end of the month) occurred in March of 1982 (102 thousand acre-feet [TAF]) and the minimum storage level occurred in December of 1974 (17 TAF). Typically, reservoir storage levels reflect the seasonal pattern of precipitation and runoff with increasing storage levels between November and March and decreasing storage levels between April and October. In an average year, storage levels typically range between 55 and 75 TAF. Calaveras Reservoir has spilled only 12 times since 1938. Spills occur between January and May and have averaged 275 cfs during the spill period.

Water quality, especially water temperature, in Calaveras Reservoir is of critical importance to development of a rainbow trout population in the creek. Reservoir releases must be cold to support trout populations, since they are most healthy at temperatures below 18°C (64°F). Other native fishes in the stream prefer higher summer water temperatures. Since water released from the reservoir warms as it moves downstream, the release temperature must be cold during the summer period to support trout. Reservoir releases must also be free of substances harmful to fish and other aquatic life.

The SFWD collects some data on reservoir water quality. Water temperature profiles were available for 1985, 1989, and 1990, and for the fall of 1984, 1987, and 1988. The water temperature profile of Calaveras Reservoir is generally isothermal in winter (November through March), ranging between 7.5° and 11°C (45.5° and 52°F). Release temperatures during this period will be suitable for downstream trout populations. Thermal stratification in the reservoir typically begins in March and the reservoir becomes fully stratified by the end of April with a warm surface layer (epilimnion) and a colder bottom layer (hypolimnion). The reservoir remains fully stratified until late October. While the reservoir is stratified, the temperature of the epilimnion typically ranges between 15° and 25°C (59° and 77°F) (Figure 2-2). During

stratification, the thermocline (transitional area between the epilimnion and hypolimnion, also referred to as the metalimnion) is generally 20 to 40 ft (6.1 to 14.0 m) below the water surface. The upper boundary of the hypolimnion is usually 30 to 40 ft (13.4 to 14.0 m) below the water surface. The water temperature of the hypolimnion ranges between 8° and 12°C (46° and 54°F), but it can be warmer in years of low storage. In October, the epilimnion begins to cool and mixes to a greater depth. At this time of year the upper layer of the hypolimnion usually descends to a depth of 40 to 50 ft (14.0 to 15.2 m) below the surface (Figure 2-3). This is the time of year when the reservoir releases are likely to be at their warmest and, therefore, it is a critical period for downstream trout populations.

As is the temperature profile, the dissolved oxygen profile of Calaveras Reservoir is related to depth. In winter when the reservoir is not stratified, dissolved oxygen levels are at their highest, ranging between 7.5 and 12 mg/l throughout the water column. During stratification, oxygen is absorbed from the atmosphere, produced in the epilimnion by photosynthesis of algae and aquatic plants, and consumed in the hypolimnion by decay processes. The high level of dissolved oxygen in the epilimnion decreases rapidly in the metalimnion and is lowest in the hypolimnion. Dissolved oxygen levels are near saturation in the epilimnion during this period, ranging between 8 and 11 mg/l. In the hypolimnion, dissolved oxygen levels stay above anoxic conditions (> 1.0 mg/l) for approximately two months following thermal stratification; however, after this point, dissolved oxygen levels drop below 1.0 mg/l. These conditions remain until destratification begins and the reservoir becomes isothermal by mid to late December. Although reservoir releases are oxygenated rapidly after they pass through the release valve, dissolved oxygen in the reservoir is important because of its effect on other water quality parameters. When oxygen is depleted in the hypolimnion, hydrogen sulfide concentrations can build to levels toxic to fish. Also, low dissolved oxygen levels create a chemical environment in which any heavy metals that may occur in reservoir sediments are moved into solution in the water column.

2.3 BAY AREA TROUT RESTORATION PROJECTS

Many local, state, and federal agencies, as well as private entities, are becoming more involved in trout habitat improvement projects throughout California. The overall decline of salmonids, especially anadromous populations, has prompted this interest. Several projects are currently underway to improve conditions for salmonid migration, spawning, rearing and holding.

In the Central Coast and San Francisco Bay area, CDFG is involved in several habitat restoration projects. In Wildcat Creek in Contra Costa County, several measures are being implemented to help restore steelhead trout populations, including creation of scour pools for summer holding habitat, restoration of riparian areas, and removal of fish passage barriers (David Brown, CDFG, pers. comm.). Wildcat Creek was stocked with individuals from a landlocked strain of coastal steelhead from Redwood Creek, a tributary of the San Leandro Reservoir, also in the East Bay Hills. This population has persisted for several years (Pete Alexander, East Bay Regional Park District, pers. comm.). Streamflows in Wildcat Creek are determined solely by local runoff with some minimal storage capacity in Jewel and Anza Lakes. Summer streamflow in Wildcat Creek is intermittent.

A habitat restoration plan for rainbow trout has been designed but not yet implemented for Walnut Creek in Central Contra Costa County. Other creeks undergoing similar habitat restoration for salmonids include Pescadero Creek in San Mateo County, Gazos Creek in Santa Cruz County, and San Pedro Creek in San Mateo County.

A few streams in the East Bay hills currently support rainbow trout populations under natural streamflow conditions, despite recent drought conditions. Tributaries of the upper San Leandro Reservoir, including Redwood and San Leandro Creeks, have supported spawning runs of rainbow trout out of the reservoir since the completion of Chabot Dam early in this century (BioSystems 1991).

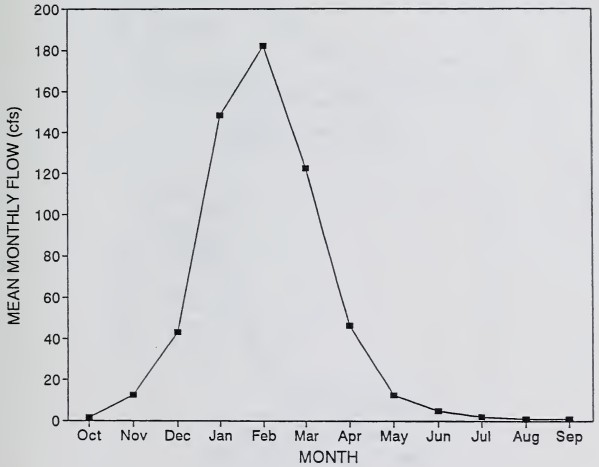
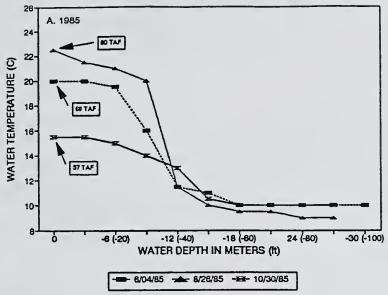
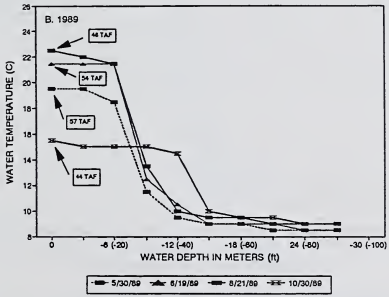


Figure 2-1. Mean monthly flow into Calaveras Reservoir (recorded at Arroyo Hondo Creek), 1969 - 1981.





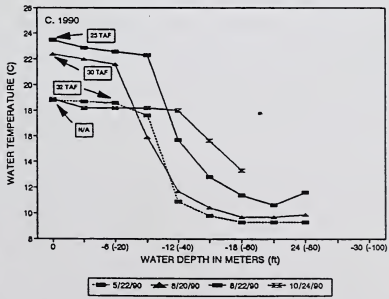


Figure 2-2. Selected water temperature profiles from Calaveras Reservoir in A) 1985, B) 1989, and C) 1990. Reservoir storage level in thousand acre-feet (TAF).

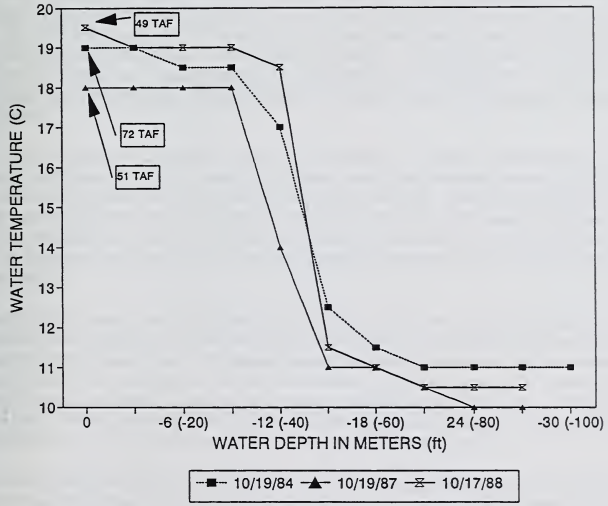


Figure 2-3. Selected October water temperature profiles from Calaveras Reservoir - 1984, 1987, and 1988. Reservoir storage level in thousand acre-feet (TAF).

3.0 HABITAT ASSESSMENT

3.1 APPROACH

There are several technical approaches for quantifying potential fish habitat at different levels of flow. These include the Instream Flow Incremental Methodology (IFIM) and the Stream Network Temperature Model (SNTEMP). The IFIM, developed by the U.S. Fish and Wildlife Service (USFWS, Bovee and Milhous 1978) determines habitat and streamflow relationships for juvenile and adult life stages of the species of concern. SNTEMP predicts instream water temperature based on stream geometry, meteorological, and hydrological conditions. Both SNTEMP and IFIM are data intensive, costly, and require monitoring data under varying flow conditions.

The IFIM is often used to establish flow recommendations for fisheries management. The IFIM indexes habitat conditions (i.e., water depth, flow velocity and substrate) under a range of flows to determine suitability for fish. Species suitability criteria for rainbow trout can be obtained from either published sources (Raleigh et al. 1984) or from information developed on the specific populations of interest or similar populations. With the IFIM, potential flow alternatives can be better examined and a more precise relationship between flow and trout habitat can be determined.

The SNTEMP model, also developed by the USFWS, solves heat transfer equations to predict instream water temperatures based on historical or synthetic hydrological, meteorological, and stream geometry conditions. The stream network consists of a series of reaches connected by nodes. Each node represents a location where either a change occurs in the stream or where model output is required. Changes in the stream include dams, tributaries, confluences, and diversion; stream geometry data include azimuth, elevation, latitude, width, and shading. SNTEMP can predict water temperatures at any point in the network.

Since the primary objective of our study was to determine whether flow at some level would provide suitable habitat conditions for trout, rather than determining the optimum level of flow for maintaining trout, we did not conduct a full IFIM study. Instead we relied on observations and data collected during experimental releases of flow from Calaveras Reservoir. We collected micro-habitat data (depth, velocity, and substrate) at several transects to determine whether suitable conditions for trout would occur at the flow levels observed and mapped the extent of different macro-habitat types (riffles, pools, etc). We also calibrated a SNTEMP model from a limited set of monitoring data collected between July and November of 1992.

Experimental flow releases were made from Calaveras Reservoir between 28 September and 1 October 1992. Experimental flows were 30 cfs on 29 September, 10 cfs on 30 September, and 5 cfs on 1 October. Habitat conditions were recorded in two experimental reaches; water quality data were collected near the release point and at two downstream locations; and stream temperature and meteorological conditions were monitored during the late summer and fall,

including the experimental flow release period. The stream temperature and meteorological data were used to calibrate the SNTEMP model for predicting stream temperatures. Although this is a very small database for developing an accurate stream temperature model, the SNTEMP model was the best tool for evaluating stream temperature under the conditions and requirements of the study.

At the time of the release, the water surface elevation of Calaveras Reservoir was 699 ft (213 m) above sea level. Storage capacity at this level is about 36 TAF. Water was withdrawn at outlet V-26 at elevation 664-668 ft (202-204 m) (G. Tosch, SFWD, pers. comm.). A water temperature profile from 22 September 1992 (the date nearest to the release date) showed the top of the hypolimnion at a depth of 30 to 40 ft (13.4 to 14.0 m) (approximate elevation 669 to 659 ft [204 to 200 m]). Estimated temperature at the withdrawal depth was between 13° and 19.5°C (55° and 67 °F) and the average hypolimnion temperature was 12°C (54°F). Based on this information, release water was being drawn from the top of the hypolimnion, or even from within the thermocline.

3.2 METHODS

3.2.1 Instream Habitat

On 2 August 1992, biologists walked the length of Calaveras Creek from below Calaveras Reservoir to its confluence with Alameda Creek and downstream from there to the Calaveras Road bridge. Based on our evaluation of stream channel morphology and habitat types, two reaches (upper and lower) were selected as representative study areas for future instream studies (Figure 3-1). The upper site had a slightly higher gradient, the stream was narrower and more confined, and the riparian vegetation was well developed and relatively undisturbed. The lower site was characterized by slightly lower gradients, the stream was relatively broad and unconfined, and the riparian vegetation had been modified by cattle grazing.

Our approach to evaluating the potential for Alameda Creek to support trout populations was twofold. Both approaches included examining stream habitat under different flow conditions. First, the composition of aquatic macro-habitat types (riffle, pool, etc) within each reach during each day of experimental flow release was measured. Secondly, micro-habitat variables such as water depth, velocity and substrate were measured across several representative transects within each reach.

The composition of aquatic habitat types was determined for each reach and flow level. The length and width of each habitat type (pool, run, riffle, cascade) was measured. In addition, the approximate amount of rainbow trout spawning habitat available within each habitat type was recorded. Spawning habitat was based on our visual observations of suitable substrate, water depth and velocity.

Prior to the experimental release, we chose several transect locations to represent spawning, pool, head of pool, and riffle habitat types. Within each reach, a total of eight transects were selected and marked with flagged rebar on both the right and left banks (looking downstream).

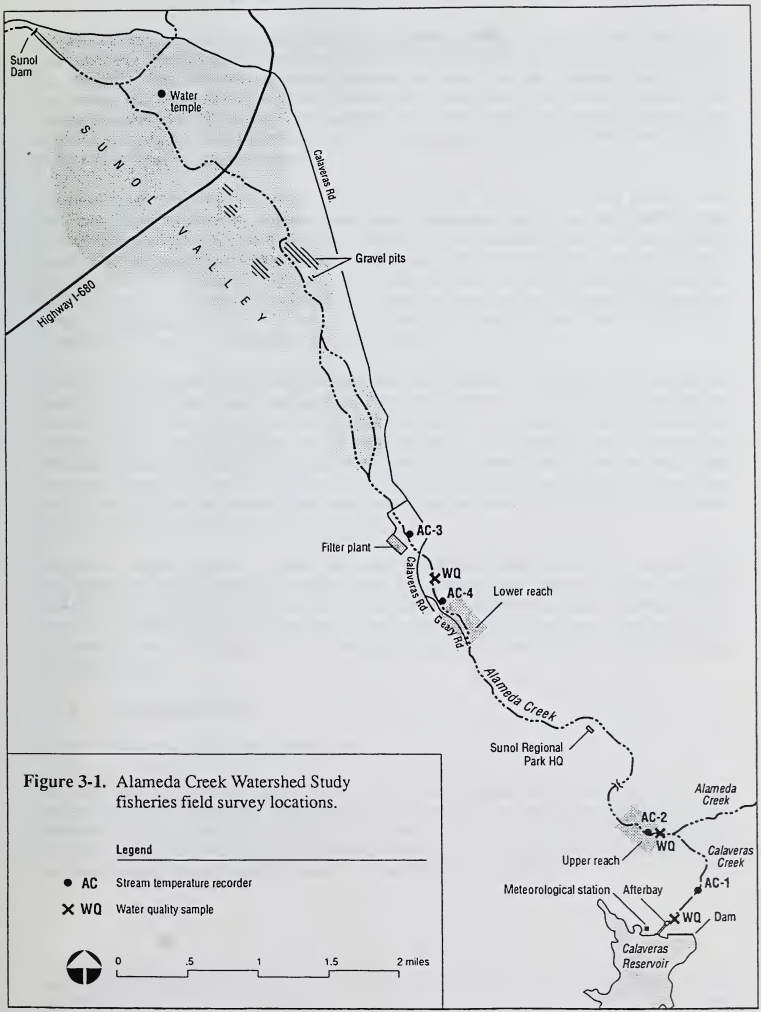


Figure 3-1. Alameda Creek Watershed Study fisheries field survey locations.

Prepared by BioSystems Analysis, Inc.

At each transect, we collected information on streambed elevation, substrate, and water depth and velocity. Channel profile and substrate data were obtained at each transect during 17-18 August 1992. We measured streambed elevation across each of the transects using a level, stadia rod, and conventional surveying techniques. These data were used to represent the channel profile at each transect. In addition, the channel gradient at each transect was determined over a 100-200 ft (30-61 m) interval by measuring upstream and downstream changes in the elevation of the channel bottom.

We determined substrate composition across each transect using the Wolman pebble count (Wolman 1954), a technique commonly employed to determine particle size distribution. One or more transects were placed from bank to bank. At each sampling point, the intermediate diameter of the pebble was measured and tallied in one of the following size classes: <2 mm, 2-4 mm, 4-8 mm, 8-16 mm, 16-32 mm, 32-64 mm, 64-128 mm, 128-256 mm, 256-512 mm, 512-1024 mm, or bedrock. A minimum of 100 pebbles were counted. These size classes are further categorized as fines (< 2 mm), fine gravel (2-16 mm), coarse gravel (16-64 mm), cobble (64-256 mm), and boulder (>256 mm) (Platts et al. 1983).

Water depth and velocity data were obtained from 29 September - 1 October 1992, during the period of experimental flow releases from Calaveras Reservoir. During each flow release scenario (30, 10, and 5 cfs), BioSystems used a Pygmy flow meter to record the depth and average column velocity (velocity at 0.6 water depth) at each sampling location along the transects. Notes were taken on the presence of other habitat features within each cell (eg., large boulders, clumps of grasses). In addition to water depth and velocity, we recorded surface water level on the right and left stream edges using a stadia rod and level. The elevation of hydraulic control was also recorded for each pool transect.

Depth and velocity recorded in each cell were scored using habitat suitability index (HSI) information developed for rainbow trout (Figure 3-2) (Raleigh et al. 1984). For each sampling location on the transect, we determined an HSI score for different lifestages (spawning, fry, juvenile, and adult). Depth and velocity scores were multiplied to produce a combined score. All scores across each transect were then averaged to produce an overall value for each lifestage at different flows.

3.2.2 Water Temperature

3.2.2.1 Data preparation for SNTEMP

SNTEMP uses six input data files: stream geometry data (channel width, elevation, etc.); time period information (temporal specification of the model); meteorological information (air temperature, wind speed, etc); study node information (desired temperature output location); hydrology node data (location of observed flows); and hydrology data (flow and water temperature data) at the hydrology nodes. A shade data file is optional.

The stream geometry data were obtained from three sources: USGS topographical maps (7.5 min series), aerial photographs taken on 27 March 1992 (Ogden Environmental and Energy Systems Company 1992), and measured transect data from BioSystems' field work (Section 3.1).

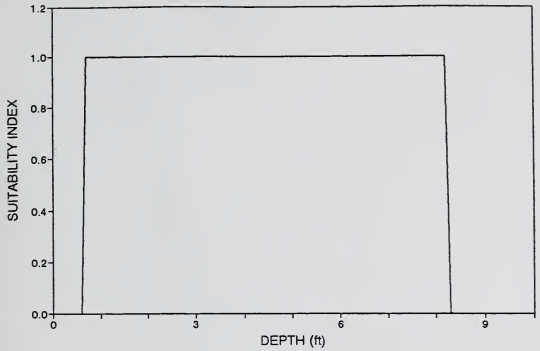
The model uses a daily time step and covers the dates from 1 August through 1 October 1992. The model's starting point was approximately 300 m (1,000 ft) downstream of the Calaveras Reservoir Afterbay at AC-1 and the end point was approximately 14.2 km (8.8 mi) downstream at the Sunol filter gallery (water temple) (Figure 3-1).

BioSystems' weather station placed near Calaveras Dam provided the meteorological data for the water temperature model between 31 July and 13 November 1992. The meteorological station included Omnidata International datapods for recording air temperature and relative humidity (Model DP220), solar radiation (Model DP221), and wind speed (Model DP214). All datapods were programmed to record at 120 min intervals.

We monitored water temperature in the creek with Omnidata International datapods (Model DP114) between July and November 1992 at four locations (Figure 3-1). This provided the temperature data for the SNTEMP model calibration. The datapods were programmed to record water temperature at 120 min intervals. The most upstream datapod (AC-1), also the beginning point of the model, was placed approximately 300 m (1,000 ft) downstream of the Calaveras Reservoir Afterbay (Figure 3-1). Datapod AC-2 was approximately 450 m (1,500 ft) downstream of the confluence of Alameda and Calaveras Creeks. The next downstream datapod (AC-4) was approximately 900 m (2,950 ft) upstream of the SFWD's filter plant. The most downstream datapod (AC-3) was adjacent to the filter plant.

Since no measured flow data are available for the creek, a flow estimate of 0.5 cfs was used for periods when no flow was released from Calaveras Reservoir (1 August through 28 September 1992). This estimate was based on observations during initial reconnaissance of the stream in August. During experimental releases between 29 September and 1 October, flow was estimated in the upper and lower reaches from water velocity data collected at BioSystems' transects. The measured data were used in the model for those three days.

Only topographical shade data were used in the shade data file. Topographical shade data were provided by Ogden Environmental and Energy Systems Company (Ogden). Although percent shade is a moderately sensitive parameter of SNTEMP, vegetative shade is an optional module of the SNTEMP model. Because of the high cost of collecting the detailed data needed, use of the shade parameter is recommended only when a stream project includes alteration of stream shading as an explicit or implicit management option. Data collected by Ogden for this purpose could not be fully incorporated into the model because of budget constraints. The impact on model calibration in this case appears to be fairly small since the model does not consistently over-estimate water temperatures. Other parameters were altered in the calibration procedure that compensated for the omission of shade date.



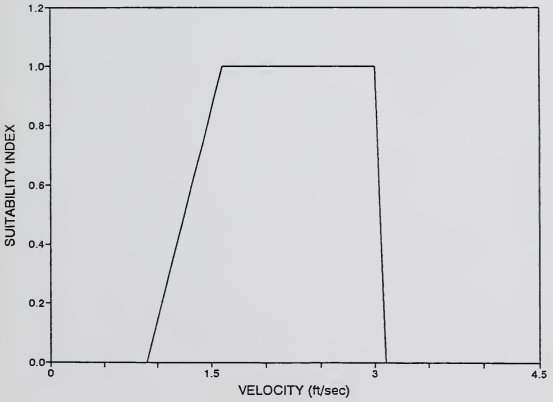
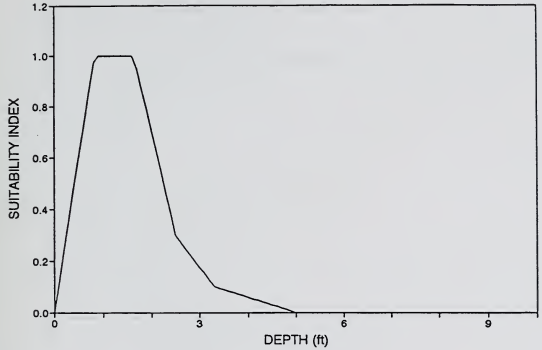


Figure 3-2a. Suitability index data for rainbow trout: spawning (from Raleigh et al. 1984).



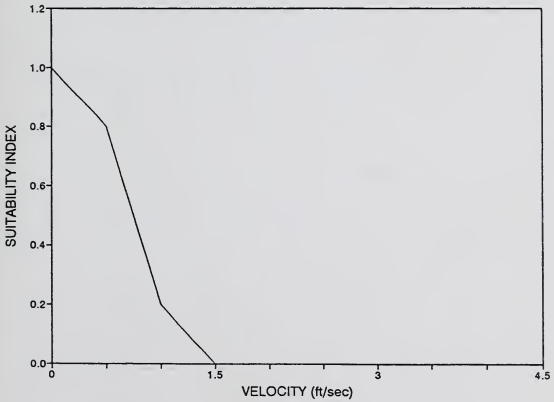
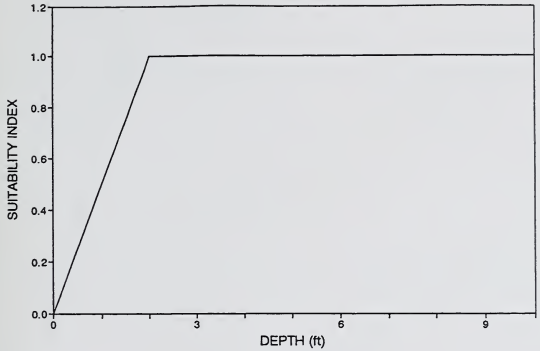


Figure 3-2b. Suitability index data for rainbow trout: fry (from Raleigh et al. 1984).



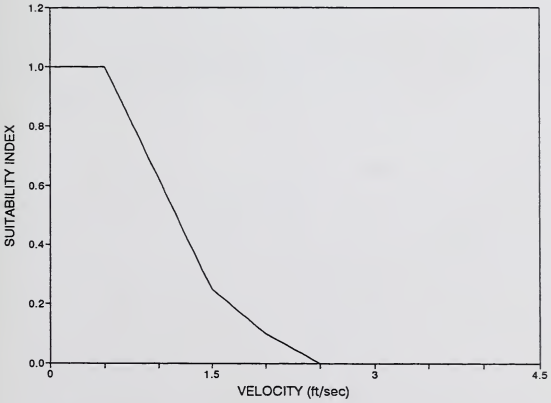
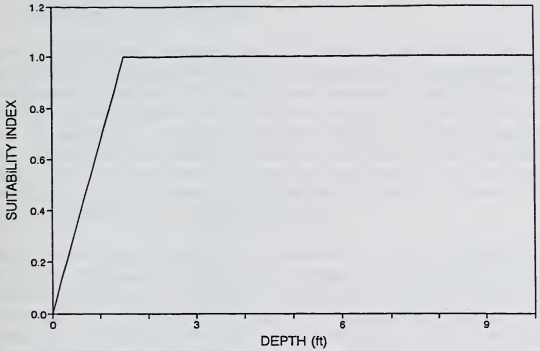


Figure 3-2c. Suitability index data for rainbow trout: juvenile (from Raleigh et al. 1984).



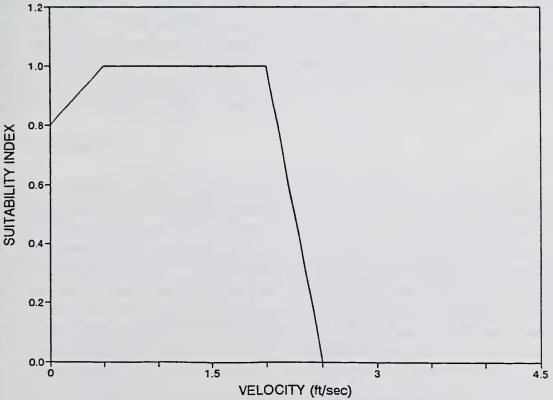


Figure 3-2d. Suitability index data for rainbow trout: adult (from Raleigh et al. 1984).

3.2.2.2 Calibration of SNTEMP Model

Calibration is the process of fine-tuning the model to simulate the system's natural dynamics as closely as possible. After compiling the data into appropriate input data format, model runs are made to calibrate the predicted with observed water temperature data. The SNTEMP model is calibrated by adjusting constants and coefficients that apply to each of the meteorological variables: air temperature, wind speed, relative humidity, percentage of sunshine, and solar radiation. Constants and coefficients are associated with each of these parameters and, if the parameters are set to a value other than zero, the meteorological variables result in a linear transformation of the original value. This transformation provides a means of correcting for local effect not detected by the meteorological station.

The choice of which meteorological variable parameter to adjust is arbitrary and varies from study to study. Parameters providing the best model performance are usually chosen. The weather station for this study was placed in an open area on a hill near Calaveras Dam. Since the weather station was not subjected to riparian and topographical shading to the same extent as the creek bed, air temperature and solar radiation recorded at the dam would likely be higher than measurements in the creek. Because air temperature and solar radiation greatly influence stream temperature, these parameters were chosen as calibration parameters.

3.2.2.3 Verification of SNTEMP

The model is verified by using the calibrated model with a different set of temperature data, either at the calibration node or at a different location in the stream. This provides a means for testing the model's performance in a condition other than the calibration condition. The AC-4 temperature data (located 900 m [2,950 ft] upstream of SFWD's filter plant) was used to test the calibrated model's performance. Verification runs are executed in the same way as the calibration runs but using a different data set.

3.2.3 Water Quality

Water quality samples were collected during each level of the flow release. Measured parameters included water temperature, dissolved oxygen, pH, and hydrogen sulfide. Duplicate samples were collected at each site for analysis of copper, iron, and manganese. The metals samples were taken because copper-sulfate has been used in the reservoir to control algae and may persist at elevated levels. High levels of solubilized iron have been noted in reservoir sampling data, and a recent spill of potassium permanganate downstream has caused interest in background levels of manganese. Samples were collected just below the Calaveras Dam Afterbay, at the upper transect site just below the Alameda Creek confluence, and at the lower transect site above Calaveras Road (Figure 3-1). Water temperature and dissolved oxygen were recorded *in situ* using a YSI meter. Water temperature was recorded only to calibrate the dissolved oxygen measurement and as a check against the instream temperature monitors (datapods). The pH was also recorded *in situ* using a LaMott pH tester (accuracy = $\pm$ 0.2 pH

units). *In situ* measurement of hydrogen sulfide was made using a Hach color comparison (Alka Seltzer™ test).

Although the sampling program conducted by BioSystems was not designed to monitor compliance with regulatory policies, we used water quality criteria developed by the EPA for the protection of aquatic life as guidelines for identifying potential water quality problems in the creek.

3.3 RESULTS

3.3.1 Instream Habitat

Aquatic habitat composition in the upper and lower reaches during the experimental release period is summarized in Table 3.1 and illustrated in Figure 3-3. In general, runs dominate aquatic habitat in the upper reach of Alameda Creek, while a more balanced composition of runs, riffles, and pools is present in the lower reach. Habitat types did not vary significantly between experimental release periods in either reach. More trout spawning habitat was available at the higher flows in both reaches (Table 3.1).

Table 3.1. Aquatic habitat composition, pool:riffle ratio, and amount of spawning habitat observed during each flow release scenario in the upper and lower reaches of Alameda Creek.

	30 CFS	10 CFS	5 CFS
Upper Reach			
Cascade	8%	2%	3%
Run	67%	74%	71%
Riffle	1%	2%	3%
Pool	24%	22%	23%
Pool :riffle ratio	24.9	14.0	8.5
Spawning habitat (m^2)	35	30	6
Lower Reach			
Cascade	1%	0%	0%
Run	48%	45%	42%
Riffle	24%	25%	24%
Pool	27%	30%	34%
Pool:riffle ratio	1.1	1.2	1.4
Spawning habitat (m^2)	30	16	6

In the upper reach, a high pool to riffle ratio was observed during all flow release periods, while the lower reach had a pool to riffle ratio closer to one (Table 3.1). Optimal river rainbow trout habitat is characterized by a 1:1 pool to riffle ratio (Raleigh et al. 1984). A similar index has not been developed for evaluating habitat conditions for native non-game fishes.

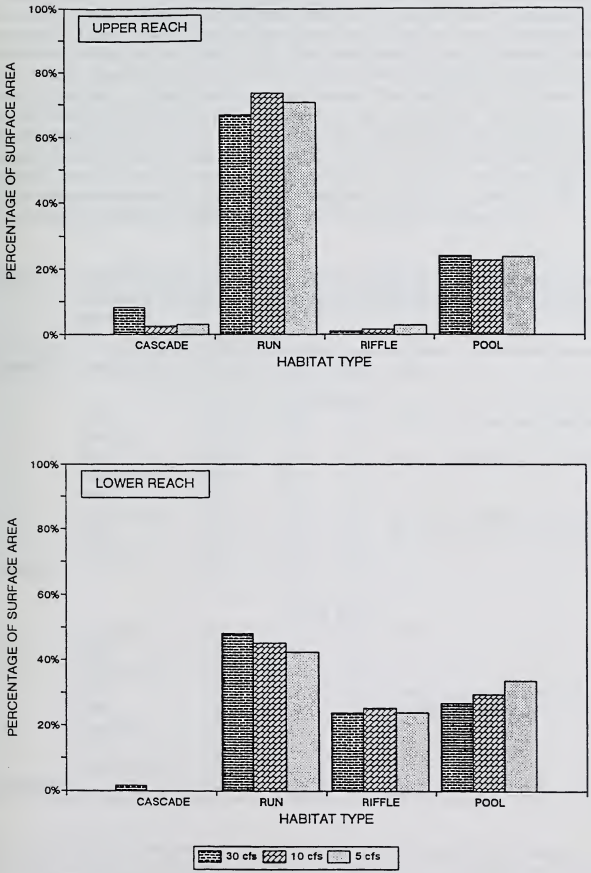


Figure 3-3. Aquatic habitat composition in the upper and lower reaches of Alameda Creek at different flows.

Although transects were not selected based on their ability to provide accurate flow estimates, we wanted to assess whether channel losses occur in the reach between Calaveras Dam and the filter plant. Using velocity data, we estimated flow (in cfs) across each transect during each experimental release period (Table 3.2). Not unexpectedly, flow estimates at each transect varied widely; however, the average of all transects was surprisingly close to the estimate of releases at the dam. In the upper reach, the average flows during the first, second, and third day of release were estimated at 28.9, 11.0, and 5.7 cfs, respectively. In the lower reach, flows were estimated at 22.6, 8.4 and 4.4 cfs. These data indicate there may have been some small channel losses under the conditions of the study. We do not think the losses are substantial in this reach, especially during periods of sustained flow. Notes on conditions that might have affected our measurements of velocity are summarized in Table 3.2. Channel profiles and water surface elevation during the three flow regimes are included in Appendix A.

Table 3.2. Estimated flow (cfs) recorded during each day of experimental release at each transect in the upper and lower reaches of Alameda Creek. NR indicates data not recorded.

TRANSECT	HABITAT TYPE	30 CFS	10 CFS	5 CFS	NOTES
			Upper Reach		
1	Riffle	28.9	13.8	6.4	Clumps of grasses obstructing flow
2	Spawning	24.3	7.6	4.7	
3	Pool	20.9	5.3	4.4	At 10 cfs, problems with velocity meter
4	Head of pool	NR	10.3	5.3	
5	Pool	NR	9.5	4.3	
6	Head of pool	41.3	16.6	8.1	At 10 cfs, problems with velocity meter
7	Riffle	28.9	11.2	5.8	At 30 cfs, flows drop midway through transect
8	Spawning	NR	16.5	6.8	
AVERAGE		**28.9**	**11.0**	**5.7**	
			Lower Reach		
1	Spawning	20.1	5.8	2.8	
2	Riffle	32.3	12.4	7.4	
3	Head of pool	26.3	9.3	4.6	
4	Pool	16.0	4.3	2.6	Clumps of grasses obstructing flow
5	Riffle	12.8	7.6	4.0	Boulders obstructing flow
6	Spawning	29.0	10.8	4.6	
7	Pool	21.7	7.5	4.6	
8	Head of pool	NR	9.8	4.9	
AVERAGE		**22.6**	**8.4**	**4.4**	

Depth and velocity scores for trout spawning, fry, juvenile, and adult lifestages of trout are illustrated for each of the transects in Figures 3-4 through 3-7. The highest attainable score of one (1.0) would indicate optimal depth and velocity conditions for a given life-stage.

Intermediate scores indicate average habitat conditions, while low scores indicate unsuitable or little available habitat. Generally, areas of high suitability occurred on all transects, but averaging all cells on a transect obscured the presence of these areas. If any transect has a high average score, this means suitability was consistently high on the entire transect. HSI scores for each transect cell are reported in Appendix B.

For spawning, average HSI scores were highest at 30 cfs but taper off at lower flows (Figure 3-4). This was consistent with observations of macro-habitat during the flow releases. On the other hand, suitable depth and velocity were found for other lifestages at all flows in both reaches. In general, flows equal to 5 cfs appear to result in slightly higher scores for fry and juvenile than those observed at higher flows (Figures 3-5 and 3-6). For adults, flows equal to 30 cfs appear to offer slightly better habitat conditions (Figure 3-7). Again, this was consistent with observations made at the time of the flow releases. We note that the differences in HSI scores between flows are small.

Substrate composition across each transect is summarized in Table 3.3. Optimal substrate size for spawning rainbow trout (<50 cm) and embryo incubation averages 15 to 60 mm in diameter (coarse gravel) (Raleigh et al. 1984). Using these size criteria, we found that suitable substrate was present in many of the transects. Coarse gravel dominated substrate type in three transects in the lower reach.

In the upper reach, stream gradient ranged between 0.4 and 2.8 percent (Table 3.3). Stream gradient in the lower reach was slightly lower, ranging from 0.2 to 1.0 percent.

3.3.2 Water Temperature

3.3.2.1 SNTEMP Simulation Runs

The goal of the simulation runs for Calaveras and Alameda Creeks was to describe the relationship between water temperature and flow rate at various locations in the creek and to serve as a tool for flow recommendations. Five simulation runs using release rates of 2, 5, 10, 15, 25, and 30 cfs with warm hydrological conditions from Calaveras Reservoir and warm meteorological conditions were made using the verified model.

Before simulation runs are made, data and parameters that influence the model, such as flow rates, water temperatures, and meteorological conditions must be defined. Meteorological and temperature conditions, as well as assumptions used in the simulation runs, are described below.

The meteorological data used in the simulation runs were the conditions that occurred on the maximum and median thermal loading days observed between AC-2 and AC-4 with a continuous input flow (in this case, 5 cfs). The thermal loading for each day between 4 and 24 August 1992 was calculated by subtracting the simulated water temperature at AC-2 from AC-4. This period was chosen because it was the time of greatest thermal loading and highest range of water temperatures. A relatively low flow of 5 cfs was used because thermal loading would be accentuated at lower flow. The maximum thermal loading day was 10 August 1992 and the median thermal loading day was 11 August 1992 (Figure 3-8). Once the maximum and the median days were determined, the corresponding observed meteorological data for those days were used for all simulated flow rates. Meteorological conditions recorded during the study period are summarized in Appendix C.

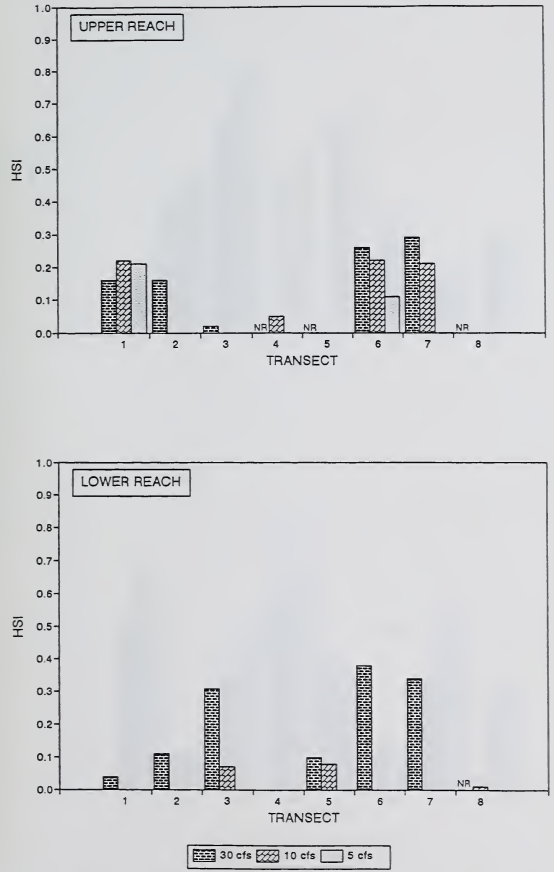


Figure 3-4. Habitat suitability index (HSI) scores for depth and velocity recorded at transects during different flows: spawning. NR indicates data not recorded (30 cfs only).

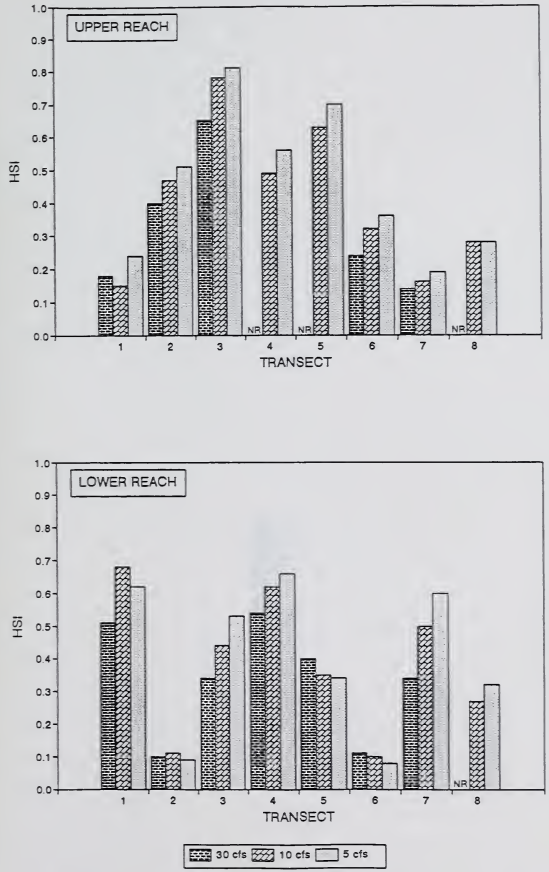


Figure 3-5. Habitat suitability index (HSI) scores for depth and velocity recorded at transects during different flows: fry. NR indicates data not recorded (30 cfs only).

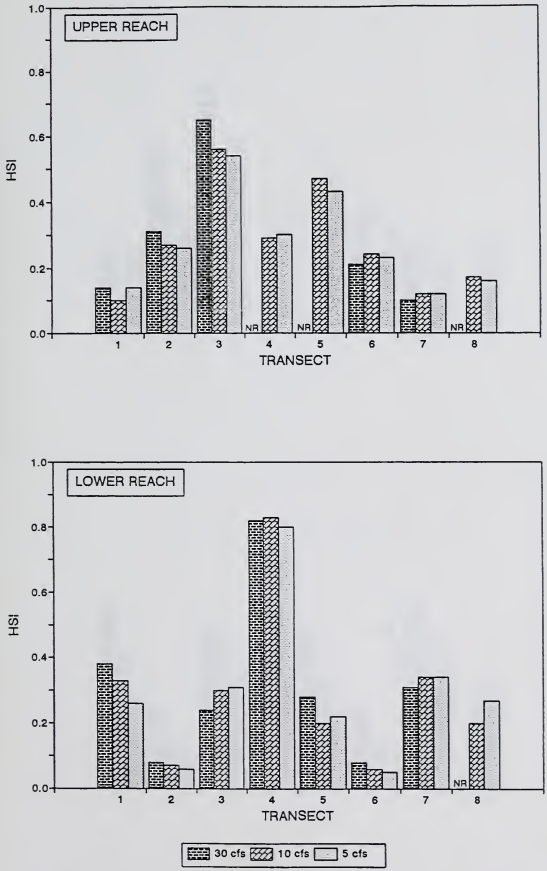


Figure 3-6. Habitat suitability index (HSI) scores for depth and velocity recorded at transects during different flows: juvenile. NR indicates data not recorded (30 cfs only).

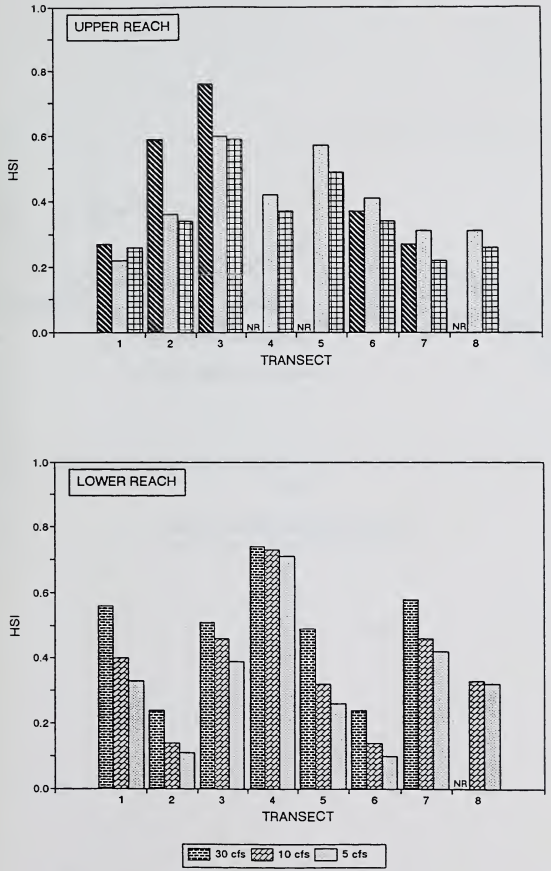


Figure 3-7. Habitat suitability index (HSI) scores for depth and velocity recorded at transects during different flows: adult. NR indicates data not recorded (30 cfs only).

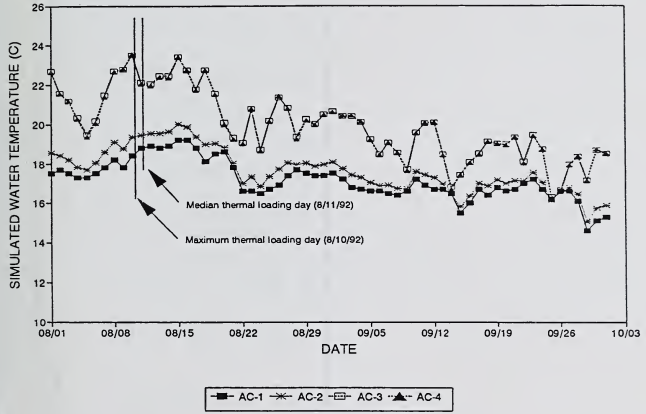


Figure 3-8. SNTEMP simulation run using 5 cfs release from Calaveras Reservoir. The maximum and median thermal loading days between AC-2 and AC-4 are labeled.

Table 3.3. Substrate composition expressed in percentages (%) across each transect as determined by Wolman pebble counts. Stream gradient is also reported.

	UPPER REACH								LOWER REACH						
TRANSECT / SUBSTRATE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7
Fines (<2 mm)	7	12	26	22	39	13	14	14	9	13	17	38	4	6	11
Fine gravel (2-16 mm)	29	44	26	33	36	32	18	62	21	27	23	23	13	39	46
Coarse gravel (16-64 mm)	27	28	22	19	14	23	7	21	37	32	27	14	23	47	33
Cobble (64-256 mm)	12	4	13	18	5	7	7	0	23	20	28	7	29	6	8
Boulder (>256)	25	12	13	3	5	2	5	0	10	8	5	18	31	2	2
Bedrock	0	0	0	5	1	23	49	3	0	0	0	0	0	0	0
Stream gradient (%)	**2.8**	**0.7**	**0.4**	**0.4**	**1.1**	**1.3**	**1.4**	**1.1**	**0.3**	**0.2**	**1.0**	**0.1**	**1.0**	**0.3**	**0.3**

These data were not sufficient to determine whether conditions that occurred in the study area in August 1992 were typical of a relatively cool, normal, or warm time period. To find out, we examined historical records from three complete weather stations maintained by NOAA (San Francisco, Stockton and Sacramento). Comparing August daily average air temperatures recorded at Calaveras Dam to these three stations, we found that the Sacramento data best represented the Calaveras data (Figure 3-9). Calaveras Dam air temperature was consistently about 4°C (7.2°F) cooler but the daily trend was very similar. In Sacramento, August 1992 was the third warmest August on record, with an average monthly temperature of 26.3°C (79.3°F), 2.1°C (3.8°F) warmer than normal. If Sacramento temperature is a good predictor of Calaveras temperature, the use of August 1992 as a source for meteorological data in the simulation runs has a conservative or worst case effect in terms of water temperature simulation.

Instream temperatures recorded by BioSystems' datapods are illustrated in Figure 3-10. Datapod malfunction and erroneous data (detected by the datapod) resulted in missing data at some locations during certain periods. The pattern and magnitude of daily fluctuations in stream water temperature is strongly influenced by air temperature, as seen in Figures 3-11 and 3-12 for AC-1 and AC-2. Compared to the water temperatures recorded at AC-1 and AC-2, daily fluctuations in water temperature at AC-3 (Figure 3-13 and 3-10) is much less. In fact, although AC-3 is 6 km (3.7 mi) downstream of AC-2, the average temperature is about 2°C (3.8°F) cooler at AC-3 or about the same as AC-1, immediately below the dam. Originally we suspected that water temperature at AC-3 was influenced by ground water during periods of little or no flow. It was later determined, however, that cold water from the filter plant is released to the stream at this location. Although SNTEMP can account for seepage or ground water influence on stream temperature, we cannot simulate this effect without specific data to accurately account for the ground water in Alameda Creek. Therefore, water temperature data obtained from AC-3 were not used to calibrate the model.

Inflow temperature (Calaveras release temperature) used in the simulation runs for the six flow rates was assumed to be 15°C (59°F); this was about the average temperature at AC-1 during the release period. Calaveras Reservoir was at a relatively low level during the study and, based on the discussion of Calaveras Reservoir thermal stratification (Section 2.2), we believe that this temperature represents the high end for release water temperature. More typical release temperature should not exceed about 12°C (54°F).

3.3.2.2 Calibration of SNTEMP

The SNTEMP model for Calaveras and Alameda Creeks covers the time period between 1 August and 1 October 1992, a total of 62 days, and includes the experimental release periods. Actual monitoring values for each day during this period were used as input data. The calibration node (AC-2) is located approximately 450 m (1,476 ft) downstream of the confluence of Alameda and Calaveras Creeks. The final calibration run resulted in a mean difference between observed and predicted water temperature of -0.1°C (−0.2°F). The maximum difference was 1.8°C (3.2°F) and the minimum difference was -2.0°C (−3.9°F) (Figure 3-14). Although a closer fit could probably be obtained with more extensive calibration data, the fit appears adequate for the purpose of this study (i.e., for a feasibility assessment).

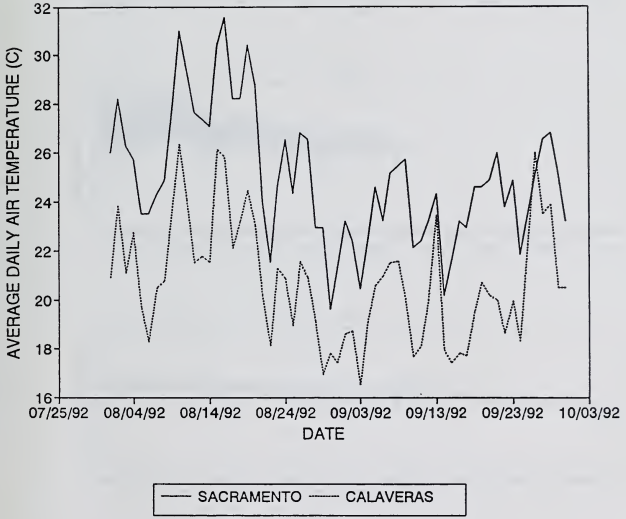


Figure 3-9. Comparison of observed average daily air temperatures from Sacramento (NOAA station) and Calaveras meteorological station (BioSystems) between 1 August and 30 September 1992.

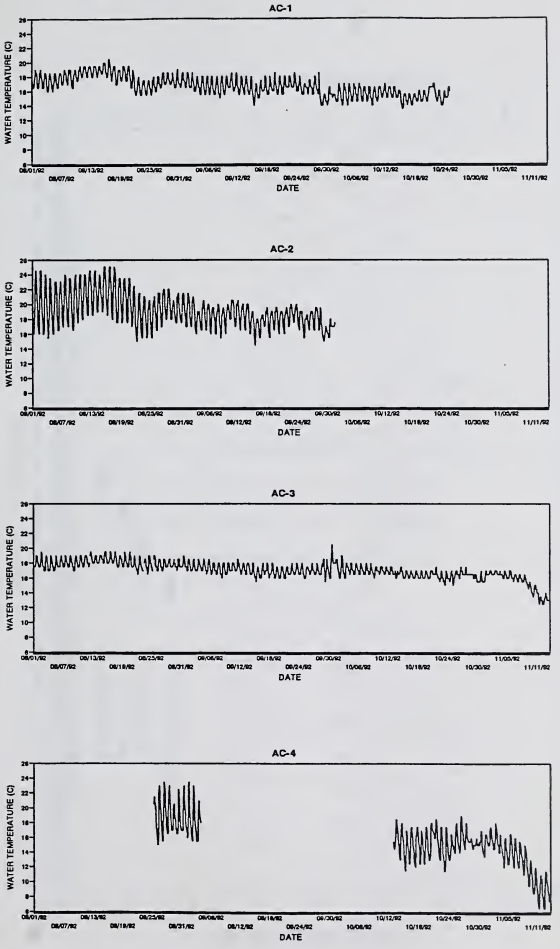


Figure 3-10. Water temperature (°C) recorded at BioSystems temperature datapods in Alameda Creek.

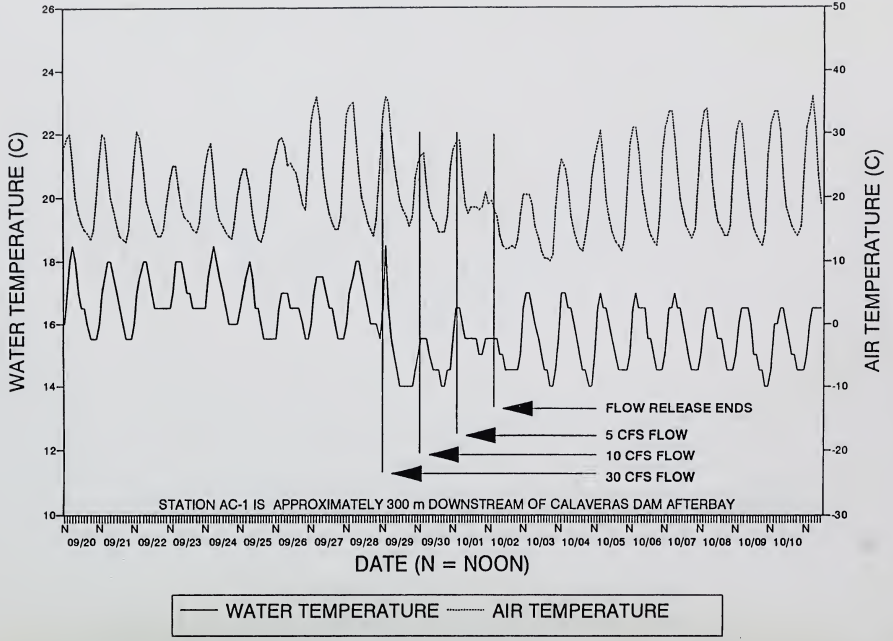


Figure 3-11. Comparison of Alameda Creek water temperature at AC-1 and Calaveras meteorological station air temperature between 20 September and 10 October 1992.

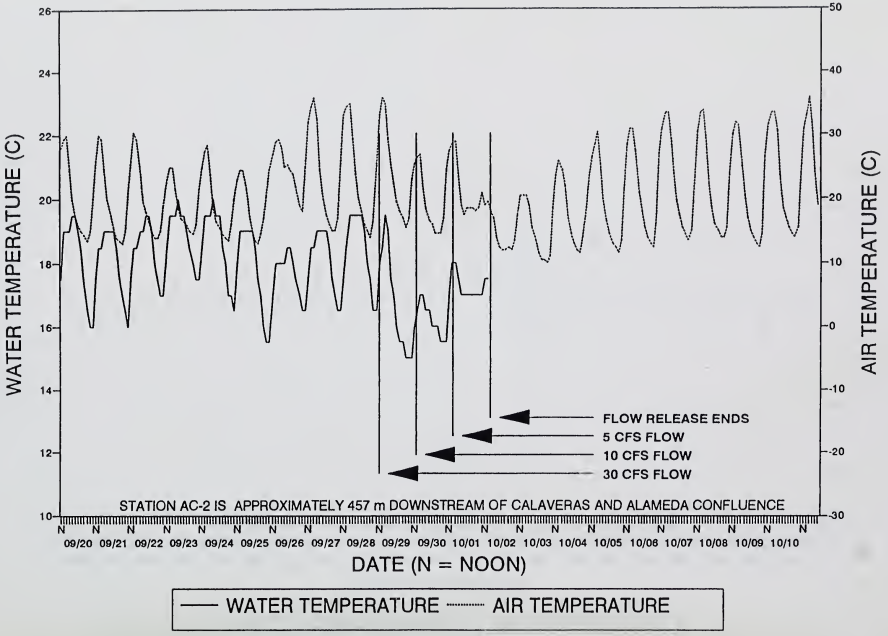


Figure 3-12. Comparison of Alameda Creek water temperature at AC-2 and Calaveras meteorological station air temperature between 20 September and 10 October 1992.

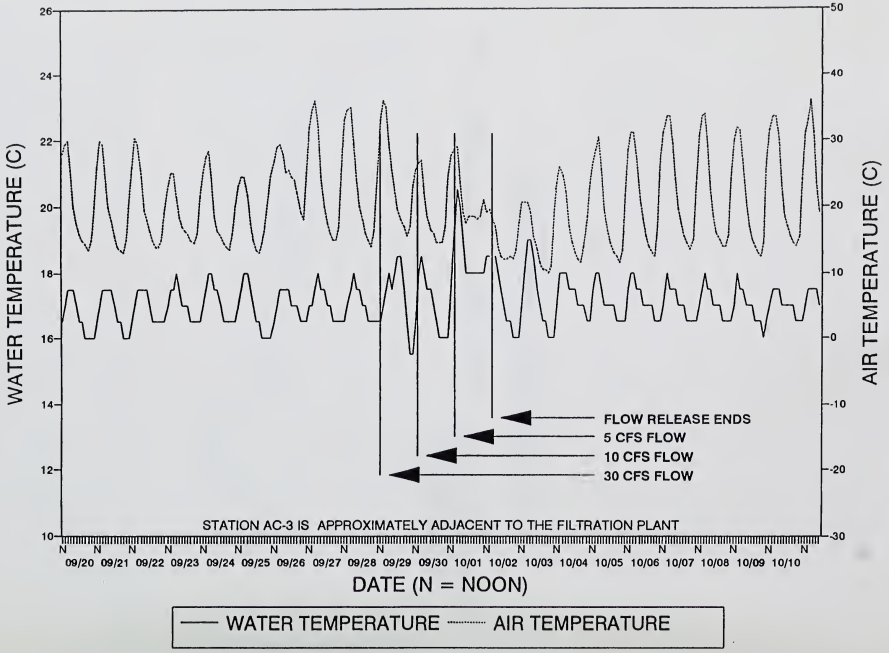


Figure 3-13. Comparison of Alameda Creek water temperature at AC-3 and Calaveras meteorological station air temperature between 20 September and 10 October 1992.

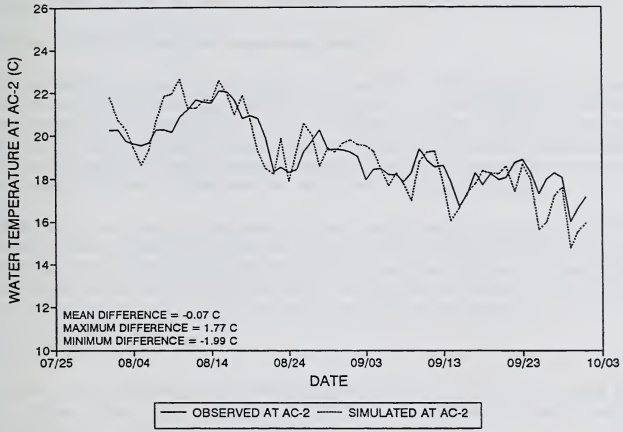


Figure 3-14. Alameda Creek SNTEMP model calibration result. Calibration node is AC-2 and calibration dates are between 1 August and 1 October 1992.

3.3.2.3 Verification of SNTEMP

Using AC-4 as the verification node, the verification model run resulted in a mean difference of 1.7°C (3.1°F) between observed and predicted water temperature. The maximum difference was 3.0°C (5.4°F) and the minimum difference was -0.3°C (-0.5°F) (Figure 3-15). It is unusual to model a stream with a limited database as in this study; however, given the situation, this verification result should be adequate for this type of feasibility study. It should be noted that the model tends to over-predict temperature at AC-4 by 1°-2°C (1.8°-3.9°F).

3.3.2.4 SNTEMP Simulated Temperature Results

The simulation results are shown in Figures 3-16 and 3-17. Simulation runs for the maximum and median thermal loading day for all flow rates show a similar pattern of increasing water temperatures moving downstream. Not surprisingly, simulation runs using the maximum thermal loading day predicted water temperatures higher than the median thermal loading day. The rate of increase in water temperature traveling downstream is greatest when the release rate was lowest (2 cfs) and smallest when the release rate was highest (30 cfs).

Based on the simulation runs and assuming a daily average water temperature of 20°C (68°F) would provide suitable conditions for trout, we concluded that flows of 15 cfs from Calaveras Reservoir during summer would provide suitable temperature conditions for trout downstream from Calaveras Dam as far as the filter plant. This flow rate is based on a worst case scenario (i.e., hottest meteorological conditions with warmest release condition).

3.3.3 Water Quality

All water quality parameters were within acceptable limits for rainbow trout during the entire flow release period. No water quality conditions were observed that would preclude the establishment of a rainbow trout population.

Dissolved oxygen levels were uniformly high throughout the release period (Table 3-4). Although the Calaveras Reservoir hypolimnion was depleted of oxygen during the release period, release of water through the new outlet valve appeared to provide complete and immediate oxygenation. Hydrogen sulfide could not be detected with the measurement method we used and hydrogen sulfide odor was not detected at any time (SFWD employees, however, reported a "foul smell" when the valve was first opened on 28 September). The pH ranged from 8 to 8.5, which is near the upper limit of the optimal range.

Copper, iron and manganese concentrations in water samples collected during the releases generally fell below EPA criteria for protection of aquatic life (EPA 1986), with a few exceptions (Table 3.4). On 29 September, the first day of high flow release, iron concentrations (998-1,015 μg/l) in the upper reach were similar to EPA's recommended instantaneous concentration of 1,000 μg/l. Iron concentrations decreased with time and distance downstream from the dam. Similarly, copper concentrations were near EPA's 4-day criteria immediately

below the dam on the first day; however, these levels also dropped with time and distance downstream. Manganese concentrations were below 150 µg/l throughout the study period; no aquatic life criteria for manganese have been recommended by EPA.

Table 3.4. Alameda Creek water quality during flow releases.

		CALAVERAS RESERVOIR RELEASE	UPPER SITE	LOWER SITE
29 Sept. 1992	Time	13:53	14:56	15:35
	Temperature (°C)	15.0	16.7	17.7
	Dissolved oxygen (mg/l)	9.2	9.8	8.5
	pH, buffer (7)	—	—	—
	pH, sample	—	—	—
	Hydrogen sulfide (mg/l)	0.0	0.0	0.0
	Copper (µg/l)*	18.5	8.5	5.5
	Iron (µg/l)**	499.0	1,006.5	197.5
	Manganese (µg/l)***	119.5	53.5	11.0
30 Sept. 1992	Time	14:02	11:07	13:30
	Temperature (°C)	16.0	16.2	19.7
	Dissolved oxygen (mg/l)	10.3	9.0	9.0
	pH, buffer (7)	7.2	7.2	7.1
	pH, sample	8.2	8.4	8.4
	Hydrogen sulfide (mg/l)	0.0	0.0	0.0
	Copper (µg/l)*	8.5	7.5	7.0
	Iron (µg/l)**	177.0	268.5	86.0
	Manganese (µg/l)***	157.5	13.0	7.5
1 Oct. 1992	Time	13:10	10:41	12:41
	Temperature (°C)	14.8	17.0	18.0
	Dissolved oxygen (mg/l)	9.6	10.2	9.4
	pH, buffer (7)	7.3	7.3	7.3
	pH, sample	8.2	8.5	8.5
	Hydrogen sulfide (mg/l)	0.0	0.0	0.0
	Copper (µg/l)*	9.0	7.0	5.0
	Iron (µg/l)**	145.5	113.5	43.5
	Manganese (µg/l)***	77.5	11.5	6.5

*EPA 1-hour criteria for protection of aquatic life is 21 µg/l based on hardness of 120 mg/l
**EPA instantaneous maximum for protection of aquatic life is 1,000 µg/l
***No criteria for manganese; aquatic life tolerance reported as 1.5 to 1,000 mg/l

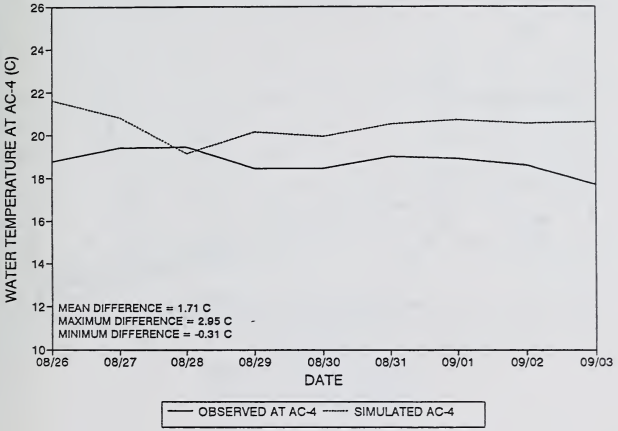


Figure 3-15. Alameda Creek SNTEMP model verification result. Verification node is AC-4 and verification dates are between 26 August and 3 September 1992.

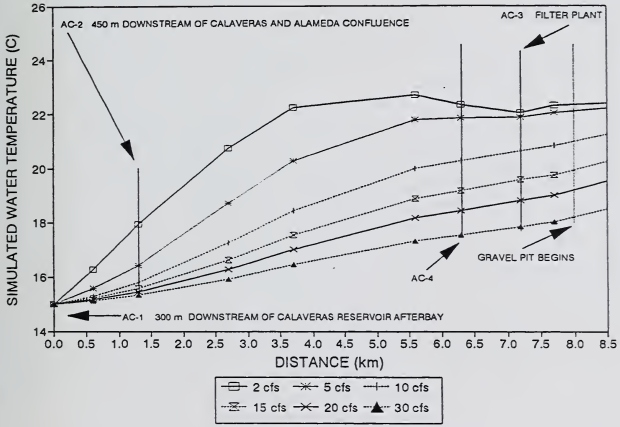


Figure 3-16. SNTEMP simulation results for Alameda Creek for median thermal loading day.

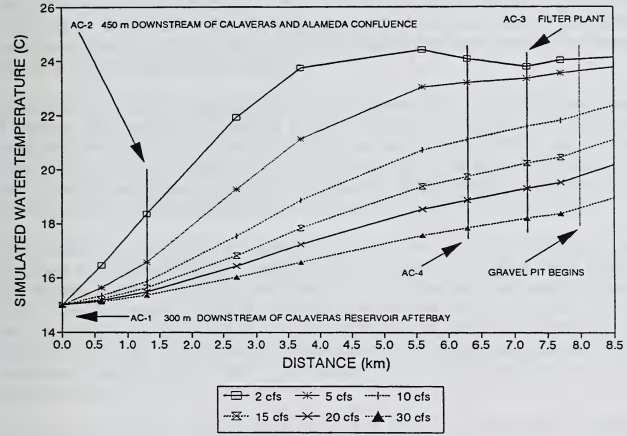


Figure 3-17. SNTEMP simulation results for Alameda Creek for maximum thermal loading day.

4.0 FISHERY MANAGEMENT OPTIONS

Our study revealed that suitable habitat conditions for trout can be maintained from Calaveras Dam downstream to the Sunol filter plant with flow augmentation. The range of flows, predicted from our modeling activities, needed to restore the trout fishery downstream to the filter plant can be provided by the SFWD under their proposed conjunctive use program. Although the trout fishery could be restored in the creek, Dr. Peter Moyle, a professor at the University of California at Davis, stated that the trout restoration efforts may result in a decline in the population of native non-game fishes. Clearly, a management plan needed to be developed for the creek which addressed these concerns.

To identify the preferred management plan for Alameda Creek, the SFWD held a meeting on 3 August, 1993 with the interested parties to solicit their input. In attendance were representatives from the University of California at Davis (Dr. Peter Moyle), California Department of Fish and Game (Cindy Chadwick and Kris Vyverberg), California Trout (Dave Baker and Michael Bowen), Bookman -Edmonston (Terry Erlewine), BioSystems (Dr. Ed Bianchi), and the SFWD (Ed Stewart, Joe Narac, Josh Milstein and Daniel Duane).

We presented five management alternatives for Alameda Creek at this meeting. These were discussed in detail and refined. The final version of each of the management alternatives is summarized in Table 4.1 and discussed below. Four alternatives recommend that the rainbow trout fishery be restored. These alternatives differ in the degree of exploitation by anglers of the trout fishery and the relative impact of each plan on the native fish community. The fifth alternative provides for protection and enhancement of the native fish community without an emphasis on rainbow trout. A preferred management plan for Alameda Creek was selected from these alternatives.

4.1 ALTERNATIVE 1—FULL EXPLOITATION OF RAINBOW TROUT FISHERY

The main objective of this alternative would be to maximize recreational fishing opportunities for trout in Alameda Creek below Calaveras Dam. Of course, some limits must apply to prevent the resource from being over-exploited. This alterative would involve an extension of the Niles Canyon fishery upstream into Sunol Regional Park. Suitable habitat conditions for trout from Calaveras Dam downstream to the Sunol filter plant would be maintained by flow augmentation. Flow augmentation would be provided to maintain cool temperatures ($<20°$ C) during the summer and to increase trout spawning habitat in the late winter.

Trout would be obtained at hatcheries and stocked in the stream to support the fishery. Although some natural reproduction may occur, it would not be relied upon to support the trout population or the fishery. This model has examples all over the state. Some notable local examples, in addition to Niles Canyon, include San Pablo Reservoir and Lake Merced in San Francisco. This approach is not unique and it is consistent with decades of fishery management practice.

Table 4.1. Potential management alternatives considered for Alameda and Calaveras Creeks on San Francisco Water District lands.

MANAGEMENT ALTERNATIVE	TARGET SPECIES	MANAGEMENT OBJECTIVE	STOCKING PROGRAM	FLOW REGIME OBJECTIVE	DISADVANTAGES
1. Full exploitation of rainbow trout fishery	Rainbow trout (native and hatchery)	Provide maximum fishing opportunity	Stocking of hatchery rainbow trout required	Provide suitable temperature ($\leq$20° C) for trout from Calaveras Dam to Sunol Filter Plan Provide spawning flow for trout	Loss of genetic stock of native rainbow trout May reduce abundance of native non-game fishes
2. Limited exploitation of rainbow trout fishery	Rainbow trout (native)	Protect genetic stock of rainbow trout Provide limited fishing opportunity	"Restocking" of stream using native rainbow trout may be required	Provide suitable temperature ($\leq$20° C) for trout from Calaveras Dam to Sunol Filter Plan Provide spawning flow for trout	May reduce abundance of native non-game fish
3. Full protection of native rainbow trout	Rainbow trout (native)	Protect genetic stock of native rainbow trout	"Restocking" of stream using native rainbow trout may be required.	Provide suitable temperature ($\leq$20° C) for trout from Calaveras Dam to Sunol Filter Plan Provide spawning flow for trout	No fishing opportunities May reduce abundance of native non-game fish
4. Protection and enhancement of native rainbow trout and native non-game fishes	Native fishes	Protect and enhance genetic stock of native rainbow trout Protect and enhance native non-game fishes	None	Improve temperature conditions for native rainbow trout in upper reach Increase habitat for native non-game fishes in lower reach	Limited fishing opportunities Trade-off between habitat conditions for rainbow trout and native non-game fish (neither maximized)
5. Protection and enhancement of native non-game fishes	Native non-game fishes	Protect and enhance native non-game fishes	None	Mimic unimpaired flow regime (summer water temperature >20° C in most areas)	No fishing opportunities Native rainbow trout may be lost

Drawbacks to this option are that, in practice, it becomes more an exercise in management of resource users than management of a resource. Implementation of this option may be in conflict with the goals of the East Bay Regional Park District which manages Sunol Park with a distinct emphasis on its wilderness values. Large numbers of recreational fishermen would degrade the riparian environment, disturb wildlife, and, as a new user group, would inevitably come into conflict with existing uses of the park. These problems would also spill over onto nearby SFWD lands.

Other drawbacks of this alternative include the potential loss of the genetic stock of native rainbow trout currently residing in the creek after hatchery fish are introduced. This loss would be significant if the resident trout are remnants of the steelhead which once made spawning runs into the creek. The abundance and species composition of the native fish population residing in the creek may also be substantially altered under the proposed flow regime. The plan would result in summer instream temperatures of less than 20° C downstream to the filter plant, with the majority of the creek less than 18° C. In general, native non-game fish populations are reduced in areas where summer instream temperatures are less than 18° C.

4.2 ALTERNATIVE 2—LIMITED EXPLOITATION OF RAINBOW TROUT FISHERY

The objective of this alternative is to provide suitable habitat conditions for native rainbow trout from Calaveras Dam downstream to the Sunol filter plant. Furthermore, once the trout population became established, a limited fishery for native trout would be developed. This alternative may require "restocking" of the creek using native rainbow trout from other stream in nearby watersheds. Since native rainbow trout populations are known to exist in Alameda Creek (below Little Yosemite area) and in Arroyo Hondo, it makes sense to use these as a source stock for restoration in Calaveras and Alameda Creeks. Flows in the creek would be increased during the summer to meet instream temperature goals and during the late winter to increase spawning habitat for trout.

This option would maintain the benefits of a native self-sustaining rainbow trout population but would also provide an exceptional fishing opportunity to a limited number of individuals. To be fair, entry to the fishery could be through a lottery, as is currently done for much waterfowl and big game hunting. The season could also be limited to a few weeks during times that would not interfere with spawning. Special gear restrictions or catch and release requirements could also be used, as could limiting the areas open to fishing.

This option could necessitate additional enforcement effort. Trout population levels would need to be carefully monitored before and after the exploitation periods to set harvest limits and other specifications. Such a fishery should be initiated only on an experimental basis, after it has been determined that the population is sufficiently healthy. Care should be taken to ensure that the level of use is low enough to protect the population and the sensitive riparian habitat. This could provide a unique, high value fishery.

The main disadvantage of this alternative is that the population of native non-game species in the creek may be adversely impacted. The proposed cool summer temperatures ($<20°$ C) for

the creek may severely restrict the range of some native species. Populations of exotic species may also increase in abundance and compete with native species under the proposed flow regime.

4.3 ALTERNATIVE 3—FULL PROTECTION OF NATIVE RAINBOW TROUT

The objective of this management alternative would be to provide conditions under which a population of genetically-distinct native rainbow trout could maintain itself in its natural environment. Stream management would provide conditions to ensure completion of each phase of the life-cycle. Flows in the creek would be augmented in the summer for temperature control and in the winter to increase spawning habitat.

Stocking hatchery strains of rainbow trout would not be consistent with this objective. With flow augmentation, the population of rainbow trout above the confluence of Alameda and Calaveras Creeks probably will expand downstream into suitable areas of the creek. If this natural process does not occur or, if it needs to be supplemented, stock from Arroyo Hondo, other Calaveras basin tributaries, or other East Bay native stock (such as San Leandro drainage) may be suitable for transplant downstream of Calaveras Reservoir. Both CDFG and Cal Trout are in favor of using native stock to repopulate the creek. The East Bay Regional Park District has used native stock from the San Leandro basin to restock Wildcat Creek below Jewel Lake, and Redwood Creek, in Redwood Regional Park, is managed for its wild trout population.

The disadvantages of this option are that no trout fishing opportunities would be developed and native non-game fishes may be adversely impacted. Increasingly, fisheries management agencies, as well as a wide spectrum of the public, are focusing on management for biotic diversity and non-consumptive values as an important goal. Although this alternative would increase the range and abundance of native trout in the Bay Area, it may actually decrease biodiversity in Alameda Creek by reducing the native non-game fish community.

4.4 ALTERNATIVE 4—PROTECTION AND ENHANCEMENT OF NATIVE RAINBOW TROUT AND NON-GAME FISHES

This alternative attempts to protect and enhance both the native rainbow trout fishery and the native non-game fishery by creating habitat conditions in Alameda Creek that benefit both populations. In this scenario, habitat conditions are not maximized for either population in the creek. Instead, the recommended flows represent a trade-off between the different requirements of the target species. Flow augmentation occurs at the same time (summer and late winter) as in the previous alternatives, but lower flows are recommended. The recommended summer flows provide suitable temperatures for trout ($<20°$ C) only in the upper half of the study area (from Calaveras Dam downstream to the Sunol Regional Park). Temperature conditions in the lower half of the creek would exceed 20° C for most of the summer; this condition is more suitable for native non-game fishes. Spawning flows in the late winter for rainbow trout would also be reduced.

A limited recreational fishery for rainbow trout could be established if the native trout population increases under this flow regime. A monitoring plan and harvest restrictions would need to be implemented to ensure protection of the trout population (details are outlined under Alterative 2). To protect the genetic integrity of the native trout population, no hatchery fish would be stocked into the watershed.

This alternative would ensure that biodiversity is maintained in the creek by improving habitat conditions for both native trout and non-game fishes. The disadvantage of this alternative is that fewer trout would be present in the creek and opportunities for angling would be reduced.

4.5 ALTERNATIVE 5—PROTECTION AND ENHANCEMENT OF NATIVE NON-GAME FISHES

The objective of the final alternative under consideration is to provide habitat conditions in the creek to maximize the protection and enhancement of the native non-game fishery. As stated earlier in our report, the habitat requirements of many native fish is not fully known, making efforts to identify flows which maximize benefits to native fishes more difficult than those for rainbow trout. Our approach to recommending flows for native fish would be to mimic the unimpaired seasonal flow pattern for the creek (shape not magnitude) and release lower flows in the summer to maintain warm instream temperatures ($>20°$ C) in the creek from Calaveras Dam downstream to the Sunol filter plant. These warmer summer temperature conditions should favor the native non-game fish community.

The disadvantage of this alternative is that the native rainbow trout fishery may be lost as well as the recreational value to sport fishermen. There is also considerable uncertainty about the effect of the recommended flows on the native non-game fishery. An annual monitoring plan would need to be implemented to document changes in the abundance and distribution of native fishes in the stream. The potential loss of rainbow trout would decrease overall biodiversity in the creek.

5.0 PREFERRED FISHERY RESTORATION PLAN

After careful deliberation, Alternative 4 (Protection and Enhancement of Native Rainbow Trout and Non-Game Fishes) was selected as the preferred alternative by all parties. Although this alternative does not maximize habitat conditions for either rainbow trout or native non-game fishes, it does provide for a balance between the requirements of these fisheries. The plan provides for a limited wild trout recreational fishery, if the population is monitored closely. Biodiversity in Alameda Creek is enhanced under this alternative with the upper half of the study reach (Calaveras Dam to Sunol Regional Park) managed for trout and other native cold-water species and the lower reach (Sunol Regional Park to the filter plant) managed for native warmwater non-game fishes. The flow and reservoir management recommendations for Alternative 4 (discussed below) are also consistent with the conjunctive use program currently being developed by the SFWD.

5.1 FLOW AND RESERVOIR MANAGEMENT

As a result of our studies, we present the following recommendations as the basis for a restoration plan for native fishes in Alameda Creek :

- **Maintain historical Calaveras Reservoir stratification conditions.**

  Using the information presented in Section 2.2, we developed a relationship between reservoir storage and volume of the hypolimnion or coldwater pool (Figure 5-1, Table 5.1). This is based on the assumption that the top of the hypolimnion occurs at a depth of 50 feet below the surface. Data on the relationship between storage and reservoir elevation were obtained from the SFWD. This relationship can be used with simulated reservoir operations to determine the volume of cold water available for fishery releases. If reservoir stratification patterns are altered in the future, the amount of hypolimnion available and release temperatures could change. In this event, the conclusions of this study, which are based on results of the SNTEMP model simulations and historic reservoir conditions, would not be valid.

- **Maintain 30 TAF in Calaveras Reservoir storage at end of October.**

  Deterioration of the hypolimnion and potentially harmful release temperatures may occur when Calaveras Reservoir storage falls below 30 TAF in the late summer, as occurred in 1990 (Figure 2-2c.). Flow release schedules should be developed to preserve this level of storage in late October. In low runoff years, spawning and rearing flows may need to be reduced to sub-optimal levels to preserve cold-water releases throughout the summer.

- **Provide a 5-day running average flow of 5 cfs immediately below the confluence of Alameda Creek and Calaveras Creek from 1 November through 31 January with a minimum mean daily flow of not less than 4.5 cfs.**

  Flows of 5 cfs provide suitable micro-habitat conditions for all rainbow trout life-stages, but field observations suggest adults may do better at higher flows. This recommendation can be refined through monitoring of the trout population and IFIM studies.

Table 5.1. Relationship between reservoir surface elevation, storage, and hypolimnion volume for Calaveras Reservoir (data from SFWD).

SURFACE ELEVATION (feet)	STORAGE (acre-feet)	HYPOLIMNION VOLUME (acre-feet)
665	13,533	135
670	16,206	970
675	18,878	1,806
680	21,551	2,641
685	25,373	3,477
690	29,195	4,312
695	33,017	5,949
700	36,839	7,586
705	41,708	9,223
710	46,576	10,860
715	51,445	13,533
720	56,313	16,206
725	61,983	18,878
730	67,652	21,551
735	73,851	25,373
740	80,050	29,195
745	86,897	33,017
750	93,745	36,839
755	100,592	41,708

- **Provide a 5-day running average flow of 20 cfs immediately below the confluence of Alameda Creek and Calaveras Creek from 1 February through 31 March with a minimum mean daily flow of not less than 18 cfs.**

  In Alameda Creek , rainbow trout appear to spawn earlier than other populations in California, with fry being observed in mid-February (R. Leidy, pers. comm.). This spawning pattern is similar to that of the historical steelhead population that made spawning runs into the creek prior to development in the watershed. This suggests that the trout population in the creek may be remnants of the historical steelhead population.

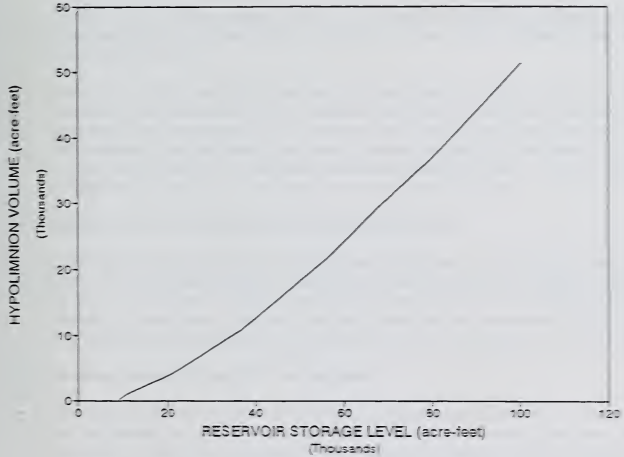


Figure 5-1. Relationship between Calaveras Reservoir storage level and the hypolimnion volume for typical October condition.

Flows of 20 cfs during the spawning period provide much better conditions than lower flows. The actual spawning period in Calaveras and Alameda Creeks should be accurately defined through spawning surveys, and the spawning flow period adjusted accordingly. Ramping up to this level early in the period may be appropriate. Most of the potential spawning habitat is in Alameda Creek below the confluence with Calaveras Creek. There may be significant runoff from Alameda Creek during the spawning period which would contribute to the target flow of 20 cfs. At these times, releases from Calaveras Dam may be reduced to 5 cfs.

- **Provide a 5-day running average flow of 7 cfs immediately below the confluence of Alameda Creek and Calaveras Creek from 1 April to 31 October with a minimum mean daily flow of not less than 6.3 cfs.**

  Flows of 7 cfs will maintain an average daily temperature of 20 °C (68 °F) or less from Calaveras Dam downstream to Sunol Regional Park during the maximum heating period. The lower reach from the regional park downstream to the filter plant will be warmer and, therefore, more suitable for the non-game native fishes. Suitable micro-habitat conditions for all lifestages of trout occur at this flow. Temperature monitoring should be used to verify the results of the SNTEMP model since it was calibrated with a very limited data base.

- **Monitor downstream temperatures to verify model results.**

  The SNTEMP model provides our best estimate of temperature conditions but it was calibrated based on a very limited data base. Monitoring of stream temperatures should be used to verify the model predictions. The flow recommendations presented here should not be taken as absolute. In many cases, it may be appropriate to maintain the recommended flow as an average over some period, such as two weeks, as long as the flow fluctuations are not extreme.

- **Evaluate the need for periodic flushing flows**

  High winter flows are important for maintaining stream channel characteristics and particularly for maintaining the clean, loose aggregations of gravel necessary for trout spawning. Historically, peak flows, averaging 120 cfs and higher in January, February, and March, may have prepared gravel beds as flows receded in March, April, and May. Evaluation of peak flows needed to maintain important channel features was not part of this study, but it is important to address this issue if trout restoration is pursued. Other approaches besides high winter flows may also be appropriate for this purpose, including placement of spawning gravel in the stream and physically loosening and cleaning existing gravel deposits using heavy machinery. The need for and implementation of these management actions should be evaluated after the population becomes established and should be based on measurements of spawning habitat characteristics and trout spawning success.

5.2 HABITAT ENHANCEMENT OPPORTUNITIES

The design of fishery restoration projects must address the specific limiting critical habitat needs, beginning with the most critical factor (Flosi and Reynolds 1991). This study has identified instream flows, especially during the summer, as the critical factor limiting trout populations in Calaveras and Alameda Creeks. The restoration plan, at this stage, should therefore focus on providing flows to meet basic habitat requirements to enhance native fish populations in the

stream. Habitat improvements and stocking are not essential to establishment of a trout population in Calaveras and Alameda Creeks. The study also identified secondary factors that may limit the fish populations after they become established. These include lack of deep-water habitat for adults and some degradation of the riparian community because of grazing in certain areas. Once instream flows are provided and native fish population are in the process of becoming established, careful monitoring should be used to identify areas where further restoration efforts may be worthwhile.

Although we do not recommend development of a habitat improvement program until further progress is made in restoring native fish populations, some preliminary recommendations can be made based on habitat data collected during BioSystems' field surveys. First, the riparian habitat along the creek should be fenced to control livestock grazing. In some areas of the lower reach of Alameda Creek, livestock grazing has resulted in thinning of riparian vegetation, loss of stream bank definition, increased sedimentation, and alteration of aquatic habitat. Reducing access of cattle to the stream channel will improve riparian and stream habitat conditions, resulting in increased fish populations (Platts and Wagstaff 1984).

Secondly, cattails in the area of Sunol Regional Park may hinder fish movement and fill in otherwise good habitat for fish. Cattails are hard to eradicate and will require more than physical removal. One method is creation of unsuitable conditions for cattail growth, such as shading and deep water (>3.5 ft [1.1 m]) (D. Brown, CDFG, pers. comm.). Intensive riparian revegetation to increase shading in areas where cattails are a problem may help to exclude them from the stream.

In the event that permanent flows are restored in the creek for the purpose of establishing a trout fishery, we recommend that the creek be further evaluated to identify potential opportunities for habitat restoration using guidelines outlined in the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds 1991). This manual includes a standardized and accepted procedure for determining habitat restoration needs based on target species, life stages, and current instream conditions.

This procedure calls for a complete stream habitat inventory, including stream classification, and channel and habitat typing. In addition, fish distribution in the stream is evaluated by conducting adult spawning surveys and determining species composition and age class. The physical habitat and fish distribution inventories are then summarized and used to determine whether a restoration project would be beneficial to the stream's fishery. In the case of Calaveras and Alameda Creeks, we would recommend that habitat and fish inventories be conducted after implementation of permanent flow releases and fish stocking program (if any).

Funding for a restoration project could be a joint venture between SFWD and East Bay Regional Parks. Also, CDFG funds salmonid restoration projects under their Fisheries Restoration and Enhancement Program. To obtain such funds, the interested party must respond to a Request for Proposal issued annually in February. The proposal must include a description of a specific program to be implemented (e.g., exclusion fencing, barrier removal, etc.). CDFG ranks all received proposals and provides funding to high priority projects.

6.0 CONCLUSIONS

During studies of water quality and flow conditions in Calaveras and Alameda Creeks and Calaveras Reservoir in the summer of 1992, no conditions were identified that would preclude development of a rainbow trout population or other native fish populations downstream of Calaveras Dam. High summer temperatures, related to low instream flow during the summer months, was identified as the major factor potentially limiting trout populations. The extent of suitable trout habitat downstream from Calaveras Dam will depend on the level of flow from the reservoir and thermal conditions within the reservoir. If reservoir stratification and storage levels are consistent with historic operation, our study indicates that suitable conditions can be maintained downstream to the filter plant throughout the summer at a flow of 15 cfs, in all but a few dry years.

The preferred management plan (Alternative 4) selected for Alameda Creek calls for the protection and enhancement of both native rainbow trout and native non-game fishes. The objective of the preferred plan is to balance the needs of these fisheries. The plan calls for the upper reach (between Calaveras Dam and Sunol Regional Park) to be managed for native rainbow trout and the lower reach (between Sunol Regional Park and the filter plant) to be managed for native, non-game, warmwater fishes. As a result, a flow of 7 cfs is recommended during the summer to meet the temperature requirements of trout down to the regional park.

No potential water quality problems involving low dissolved oxygen, high concentrations of hydrogen sulfide, high turbidity, unsuitable pH, and high levels of dissolved metals were encountered during experimental flow releases. Reservoir levels during the study period were low because of several years of below normal rainfall; therefore, water quality conditions should have been at or near their worst levels.

Suitable habitat conditions for rainbow trout were observed at 30, 10, and 5 cfs. Although this study was not specifically designed to determine the optimum level of flow for rainbow trout, observations indicated that conditions for adults and for spawning were probably greatest at the highest flow level observed (30 cfs). We recommend only 20 cfs be released into the creek during trout spawning because the preferred management plan is not directed solely at maximizing conditions for trout.

Physical habitat improvement projects that create deeper pools and increase instream cover may increase adult habitat at lower flow levels. Conditions for fry and juvenile life-stages appeared reasonably good at all flow levels. Exclusion of cattle from the riparian zone would probably benefit instream habitat. It may be possible to improve habitat by planting riparian vegetation; however, the riparian zone between the dam and the filter plant is in relatively good condition.

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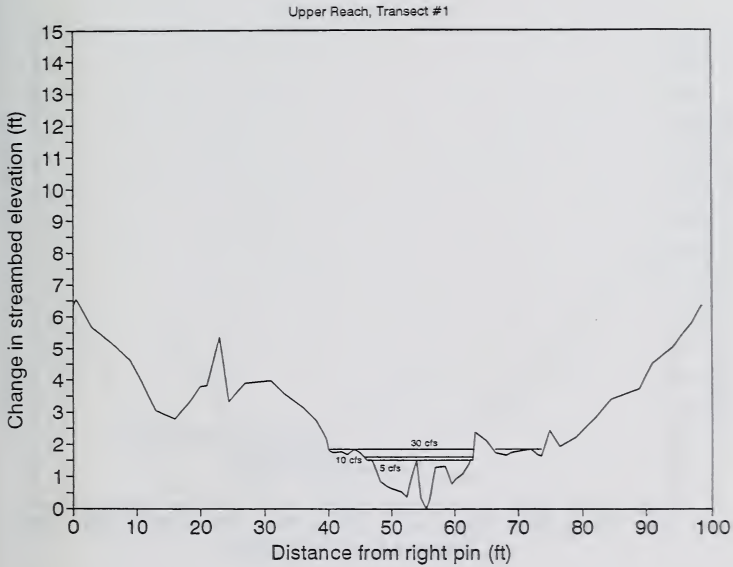
APPENDIX A.

TRANSECT CROSS-SECTIONS AND WATER SURFACE PROFILES


Upper Reach, Transect #1
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
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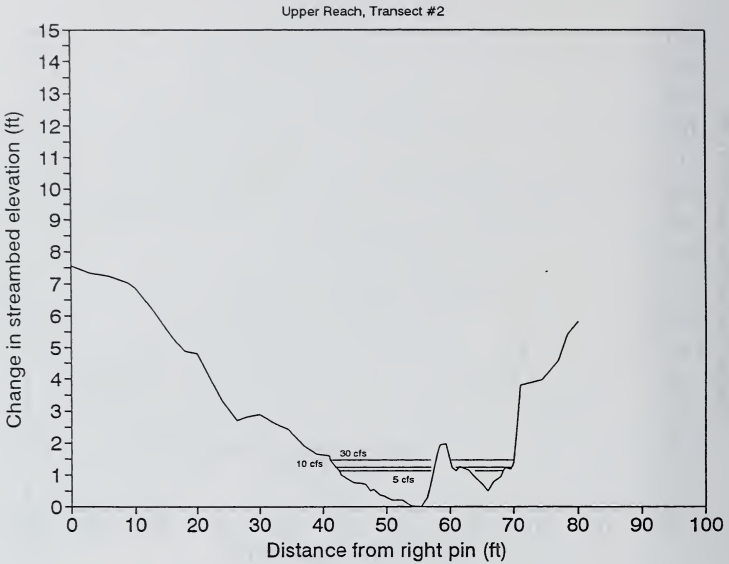
Upper Reach, Transect #2
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
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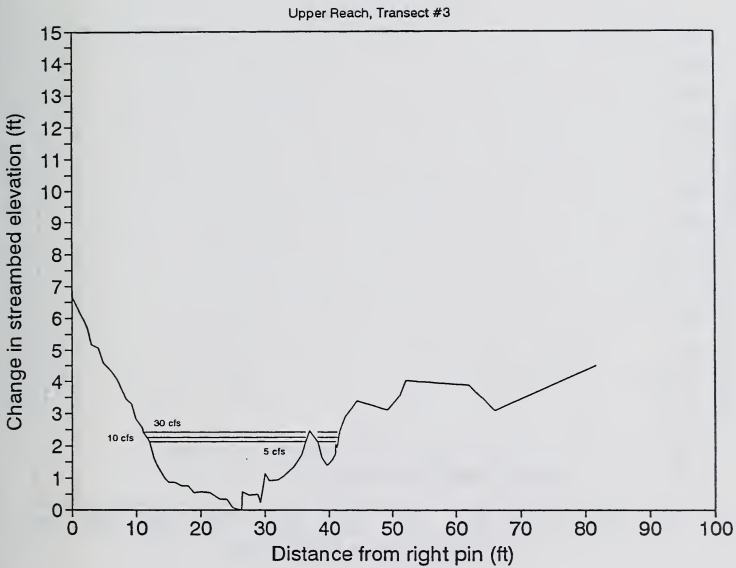
Upper Reach, Transect #3
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
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7
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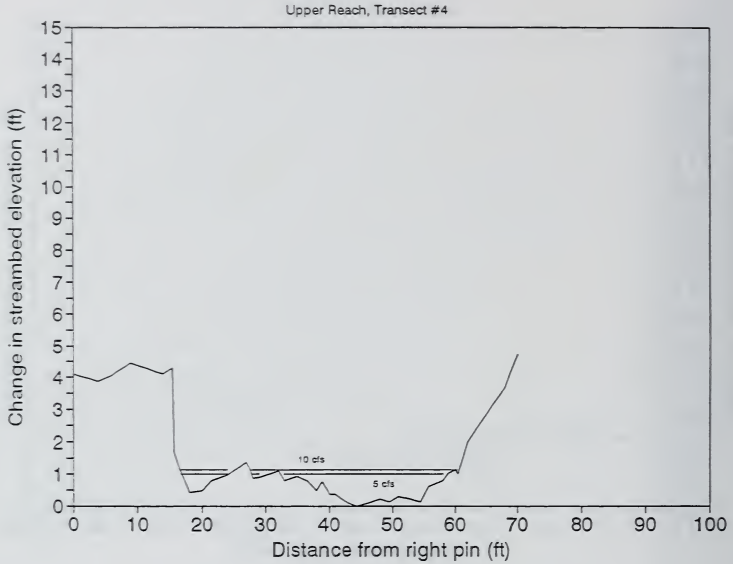
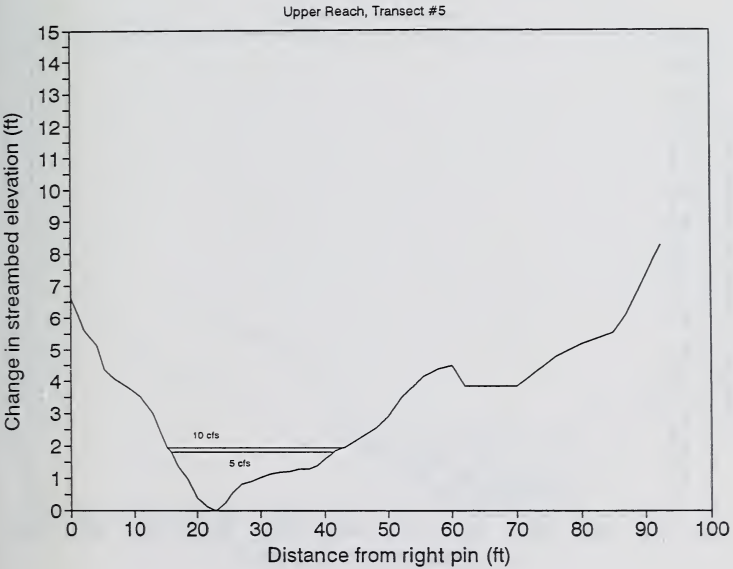
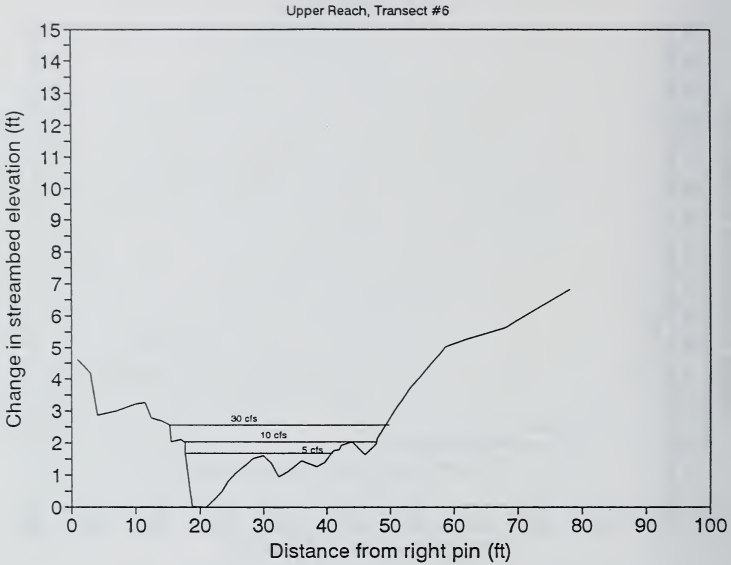
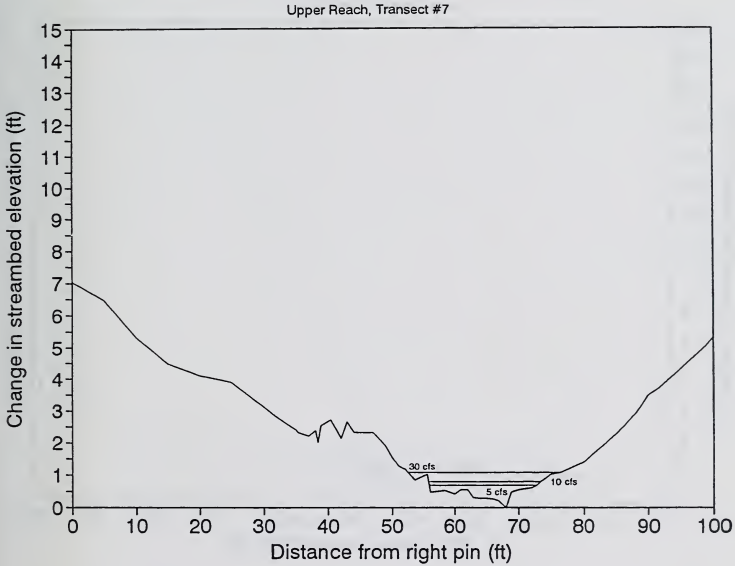
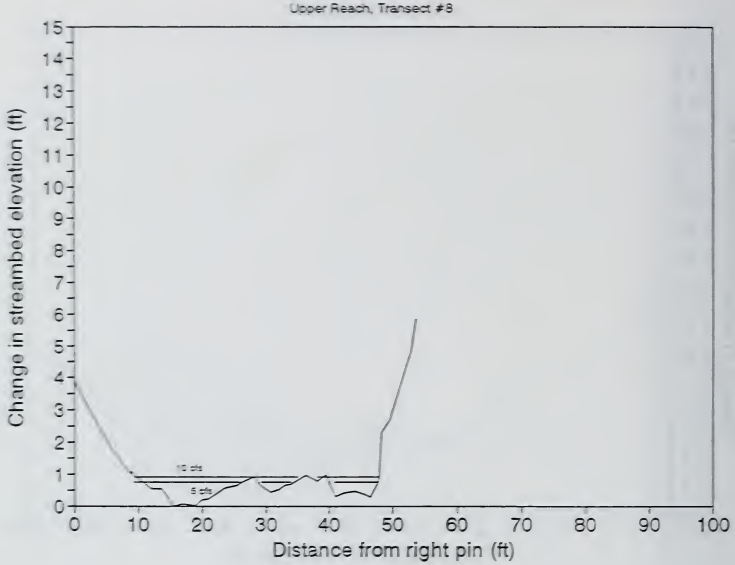
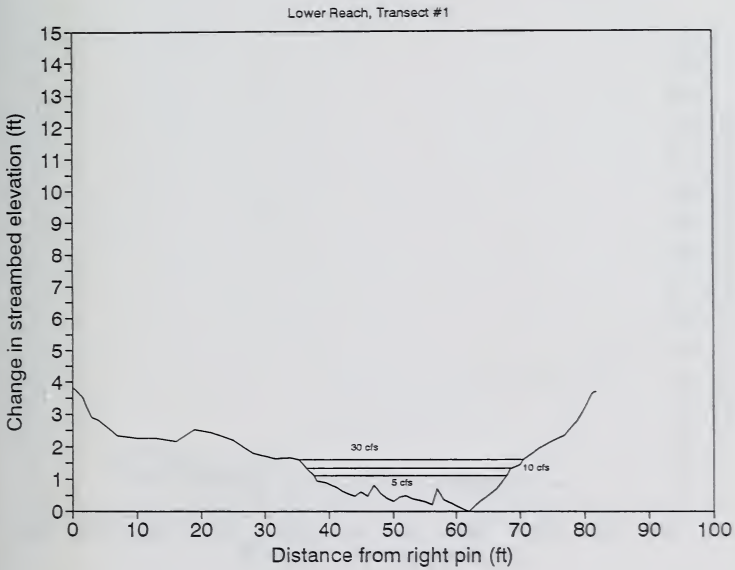

Upper Reach, Transect #4
Change in streambed elevation (ft)
Distance from right pin (ft)
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100

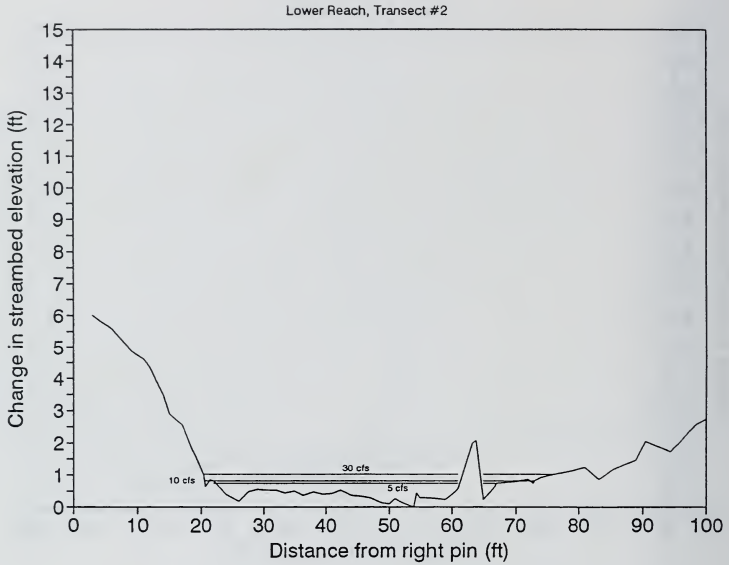

Upper Reach, Transect #5
Change in streambed elevation (ft)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10 cfs
5 cfs
0
10
20
30
40
50
60
70
80
90
100
Distance from right pin (ft)

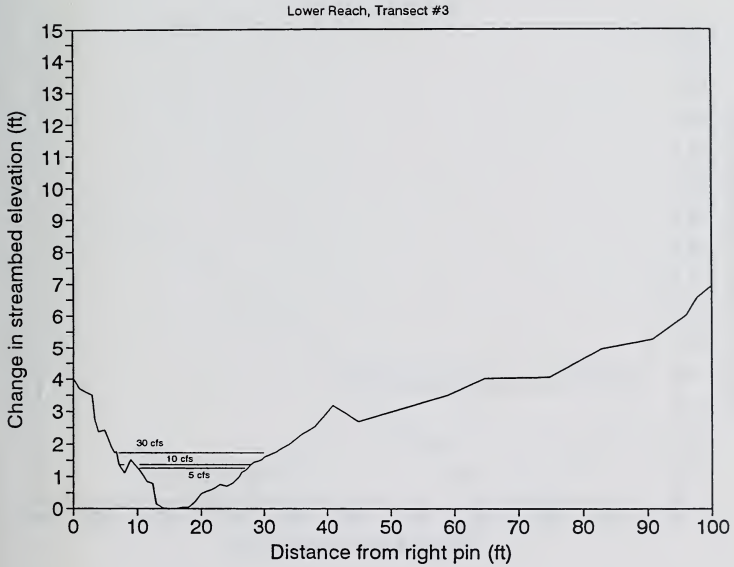

Upper Reach, Transect #6
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100

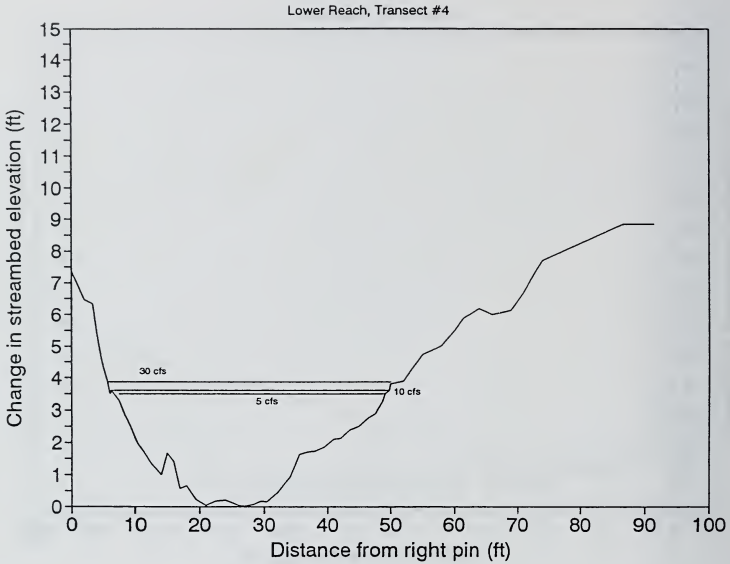

Upper Reach, Transect #7
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100

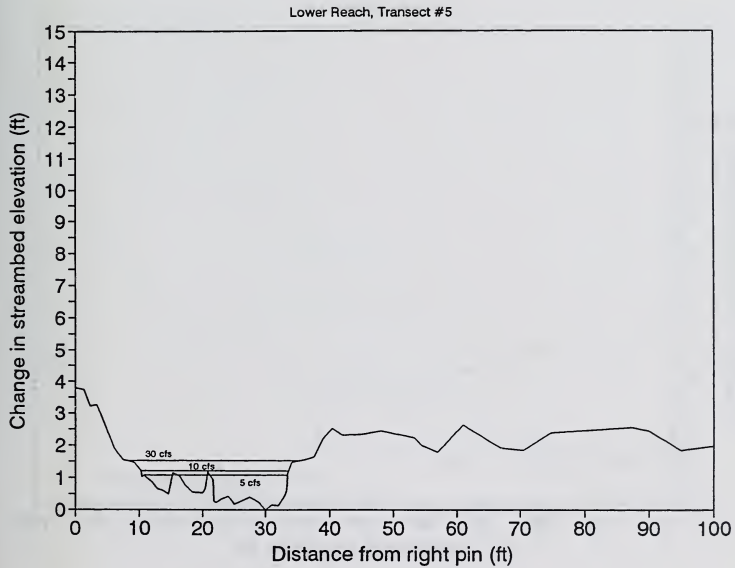

Upper Reach, Transect #8
Change in streambed elevation (ft)
Distance from right pin (ft)
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100

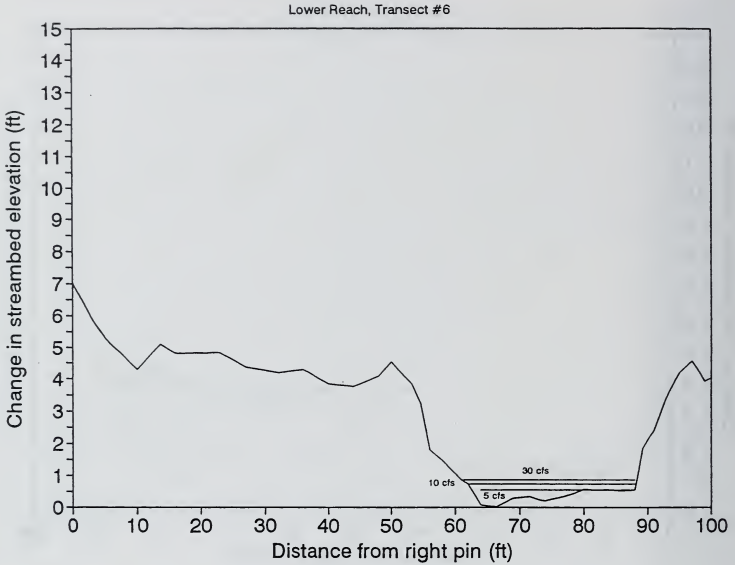

Lower Reach, Transect #1
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100


Lower Reach, Transect #2
Change in streambed elevation (ft)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
30 cfs
10 cfs
5 cfs
0
10
20
30
40
50
60
70
80
90
100
Distance from right pin (ft)


Lower Reach, Transect #3
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100


Lower Reach, Transect #4
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100


Lower Reach, Transect #5
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100


Lower Reach, Transect #6
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
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8
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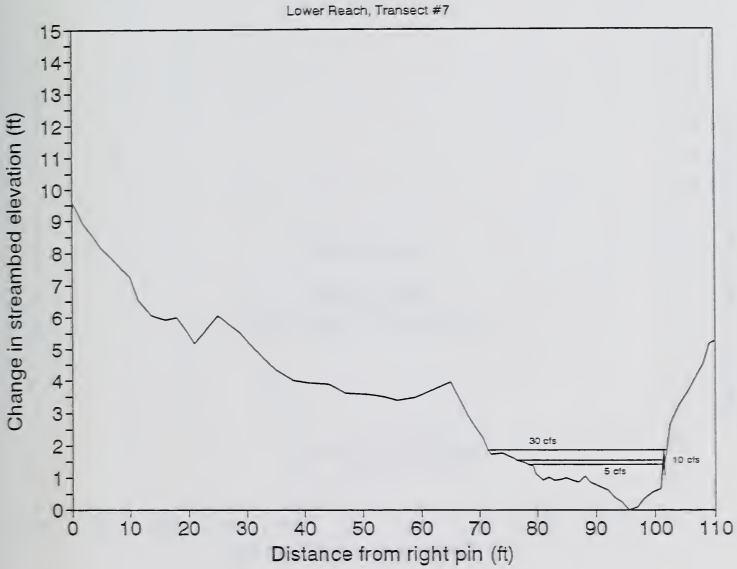
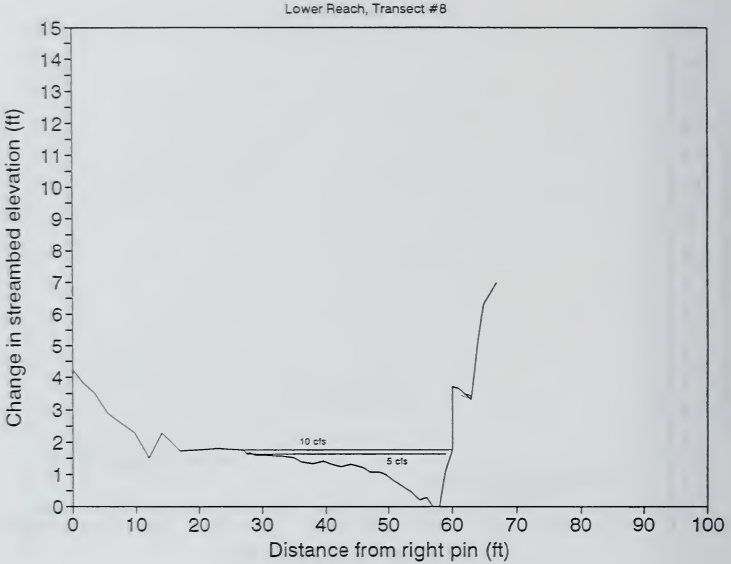
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100


Lower Reach, Transect #7
Change in streambed elevation (ft)
Distance from right pin (ft)
30 cfs
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100
110


Lower Reach, Transect #8
Change in streambed elevation (ft)
Distance from right pin (ft)
10 cfs
5 cfs
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
90
100

APPENDIX B.

HSI SCORES FOR FLOW TRANSECTS

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 1
TRANS 1

			HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	DEPTH (ft)	VELOCITY (ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
30 cfs														
46.0	1.0		1.00	0.00	1.00	1.00	0.50	1.00	0.87	0.90	0.00	1.00	0.50	0.53
45.7	0.3	1.01	0.00	0.19	0.24	0.20	0.10	0.82	0.13	1.00	0.00	0.05	0.08	0.13
45.5	0.2	0.89	0.00	0.00	0.24	0.34	0.10	0.71	0.13	1.00	0.00	0.08	0.07	0.13
45.0	0.3	1.14	0.00	0.34	0.27	0.19	0.10	0.82	0.26	1.00	0.00	0.05	0.08	0.26
44.5	0.3	0.44	0.00	0.00	0.24	0.82	0.10	1.00	0.13	0.38	0.00	0.20	0.10	0.13
44.3	0.2	0.03	0.00	0.00	0.24	0.99	0.10	1.00	0.13	0.01	0.00	0.24	0.10	0.11
44.0	0.3	0.81	0.00	0.00	0.61	0.43	0.25	0.77	0.29	1.00	0.00	0.00	0.19	0.29
43.8	0.2	1.27	0.00	0.53	0.73	0.08	0.30	0.42	0.40	1.00	0.00	0.07	0.13	0.40
46.3	1.2	2.40	1.00	1.00	1.00	0.00	0.50	0.00	0.87	0.01	1.00	0.01	0.00	0.01
46.2	1.2	1.20	1.00	0.87	1.00	0.98	0.85	0.45	0.87	1.00	0.87	0.98	0.85	0.87
46.0	1.1	0.99	1.00	0.98	1.00	0.26	0.95	0.94	0.73	1.00	0.98	0.26	0.98	0.73
61.8	1.2	0.74	1.00	0.00	1.00	0.52	0.85	0.82	0.87	1.00	0.00	0.52	0.53	0.87
62.4	1.2	2.01	1.00	0.84	1.00	0.00	0.90	0.00	1.00	0.00	0.84	0.00	0.00	0.00
63.0	1.1	2.73	1.00	0.00	1.00	0.00	0.95	0.00	0.73	0.00	0.00	0.00	0.00	0.00
64.0	0.4	3.89	0.00	1.00	0.49	0.00	0.20	0.00	0.27	0.00	0.00	0.00	0.00	0.00
64.7	0.4	4.38	0.00	0.00	0.49	0.00	0.20	0.00	0.27	0.00	0.00	0.00	0.00	0.00
66.6	1.6	3.80	1.00	0.00	1.00	0.00	0.75	0.00	1.00	0.00	0.00	0.00	0.00	0.00
68.0	1.8	3.13	1.00	0.00	1.00	0.00	0.90	0.00	1.00	0.00	0.00	0.00	0.00	0.00
67.0	0.6	0.03	0.00	0.99	0.81	0.99	0.35	1.00	0.33	0.01	0.00	0.80	0.35	0.27
68.6	1.1	0.39	1.00	0.00	1.00	0.94	0.65	1.00	0.73	0.96	0.00	0.94	0.65	0.75
69.2	1.0	1.42	1.00	0.78	1.00	0.03	0.50	0.30	0.87	1.00	0.78	0.03	0.15	0.87
81.2	0.7	1.49	1.00	0.85	0.96	0.00	0.35	0.25	0.47	1.00	0.85	0.00	0.08	0.47
81.8	0.6	0.64	0.00	0.00	0.73	0.63	0.20	0.90	0.40	1.00	0.00	0.46	0.27	0.40
82.6	0.4	0.43	0.00	0.00	0.49	0.82	0.20	1.00	0.27	0.67	0.00	0.41	0.20	0.26
88.2	0.2	0.02	0.00	0.00	0.24	0.99	0.10	1.00	0.13	0.01	0.00	0.24	0.10	0.11
73.3	0.1		0.00	0.00	0.13	1.00	0.05	1.00	0.07	0.80	0.00	0.13	0.05	0.06
AVERAGE			0.48	0.24	0.69	0.35	0.37	0.55	0.49	0.69	0.19	0.21	0.19	0.28
10 cfs														
46.0	0.1	0.78	0.00	0.00	0.12	0.46	0.05	0.79	0.07	1.00	0.00	0.08	0.04	0.07
47.0	0.1	0.98	0.00	0.13	0.12	0.22	0.05	0.64	0.07	1.00	0.00	0.03	0.03	0.07
46.2	0.7	1.59	1.00	0.99	0.85	0.00	0.35	0.23	0.47	1.00	0.99	0.00	0.08	0.47
48.2	0.8	0.89	1.00	0.00	0.98	0.56	0.40	0.86	0.53	1.00	0.00	0.56	0.34	0.53
50.0	0.8	2.06	1.00	1.00	1.00	0.00	0.45	0.00	0.60	0.84	1.00	0.00	0.00	0.50
51.8	0.9	0.81	1.00	0.00	1.00	0.43	0.45	0.77	0.60	1.00	0.00	0.43	0.36	0.60
52.4	1.1	2.01	1.00	1.00	1.00	0.00	0.55	0.10	0.73	0.98	1.00	0.00	0.06	0.73
53.0	0.9	3.15	1.00	0.00	1.00	0.00	0.45	0.00	0.60	0.00	0.00	0.00	0.00	0.00
54.0	<0.1		0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.80	0.00	0.00	0.00	0.00
54.7	<0.1		0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.80	0.00	0.00	0.00	0.00
55.5	1.0	3.36	1.00	0.00	1.00	0.00	0.50	0.00	0.47	0.00	0.00	0.00	0.00	0.00
54.0	1.1	2.98	1.00	1.00	1.00	0.00	0.55	0.00	0.73	0.00	1.00	0.00	0.00	0.00
57.0	0.2	0.03	0.00	0.00	0.24	0.99	0.10	1.00	0.13	0.01	0.00	0.24	0.10	0.11
60.2	0.3	0.39	0.00	0.00	0.73	0.94	0.30	1.00	0.40	0.96	0.00	0.92	0.30	0.38
61.2	0.4	0.78	0.00	0.00	0.49	0.49	0.20	0.80	0.27	1.00	0.00	0.24	0.18	0.27
61.8	0.2	0.00	0.00	0.00	0.37	1.00	0.15	1.00	0.20	0.00	0.00	0.37	0.15	0.20
62.6	0.1	0.02	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.81	0.00	0.13	0.05	0.06
62.8	0.1	0.00	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.81	0.00	0.13	0.05	0.06
AVERAGE			0.44	0.23	0.54	0.60	0.28	0.83	0.34	0.76	0.22	0.18	0.10	0.22
5 cfs														
47.0	0.0		0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.80	0.00	0.00	0.00	0.00
46.2	0.6	0.54	0.00	0.00	0.81	0.96	0.25	1.00	0.33	0.92	0.00	0.80	0.25	0.27
48.2	0.8	1.15	1.00	0.36	0.73	0.14	0.30	0.51	0.40	1.00	0.00	0.10	0.15	0.40
50.0	0.8	0.22	0.00	0.00	0.73	0.81	0.30	1.00	0.40	0.98	0.00	0.80	0.30	0.38
51.8	0.9	0.81	1.00	0.00	0.98	0.66	0.40	0.81	0.53	1.00	0.00	0.65	0.37	0.53
52.4	0.8	1.26	1.00	0.50	1.00	0.19	0.45	0.44	0.60	1.00	0.50	0.19	0.20	0.60
53.0	0.5	2.96	0.00	1.00	0.81	0.00	0.25	0.00	0.33	0.00	0.00	0.00	0.00	0.00
54.0	0.9	2.47	1.00	1.00	0.98	0.00	0.40	0.00	0.53	0.04	1.00	0.00	0.00	0.03
54.0	1.0	3.23	1.00	1.00	1.00	0.00	0.50	0.00	0.87	0.00	1.00	0.00	0.00	0.00
60.2	0.5	0.58	0.00	0.00	0.81	0.79	0.25	0.94	0.33	1.00	0.00	0.42	0.23	0.33
61.2	0.3	0.84	0.00	0.00	0.37	0.63	0.15	0.90	0.20	1.00	0.00	0.23	0.13	0.20
61.8	0.1	0.00	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.81	0.00	0.13	0.05	0.05
AVERAGE			0.20	0.30	0.64	0.51	0.26	0.65	0.27	0.74	0.21	0.24	0.14	0.24

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 1
TRANS 2

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
30 cfs														
40.8	0.7	0.07	1.00	0.09	0.95	0.87	0.35	1.00	0.47	0.83	0.09	0.83	0.35	0.38
40.9	0.7	0.07	1.00	0.09	0.95	0.87	0.35	1.00	0.47	0.83	0.09	0.83	0.35	0.38
41.0	0.7	0.06	1.00	0.08	0.95	0.89	0.35	1.00	0.47	0.81	0.08	0.85	0.35	0.38
41.1	0.8	0.06	1.00	0.08	1.00	0.87	0.45	1.00	0.60	0.83	0.08	0.87	0.45	0.50
41.2	0.8	0.03	1.00	0.05	1.00	0.99	0.45	1.00	0.60	0.91	0.05	0.99	0.45	0.55
41.3	1.1	0.08	1.00	0.00	1.00	0.97	0.58	1.00	0.73	0.93	0.00	0.97	0.58	0.81
41.4	1.2	0.20	1.00	0.00	1.00	0.81	0.85	1.00	0.97	0.88	0.00	0.81	0.85	0.77
41.5	1.2	0.79	1.00	0.00	1.00	0.46	0.90	0.78	0.99	1.00	0.00	0.46	0.70	0.80
41.6	1.3	1.13	1.00	0.31	1.00	0.16	0.95	0.64	0.97	1.00	0.31	0.16	0.35	0.97
41.8	1.5	0.98	1.00	1.00	1.00	0.00	0.75	0.98	1.00	0.94	1.00	0.00	0.00	0.94
42.0	1.2	1.41	1.00	0.73	1.00	0.04	0.75	0.33	1.00	1.00	0.73	0.04	0.24	1.00
42.2	1.0	1.36	1.00	0.88	0.97	0.06	0.60	0.36	1.00	1.00	0.88	0.06	0.20	1.00
42.5	1.0	0.81	1.00	0.00	1.00	0.43	0.90	0.77	1.00	1.00	0.00	0.43	0.81	1.00
42.8	1.4	0.96	1.00	0.00	1.00	0.37	0.70	0.73	0.93	1.00	0.00	0.37	0.51	0.93
43.0	1.2	1.08	1.00	0.25	1.00	0.17	0.60	0.57	0.80	1.00	0.25	0.17	0.34	0.80
43.3	0.4	1.81	0.00	1.00	0.48	0.00	0.20	0.18	0.27	1.00	0.00	0.00	0.00	0.27
43.5	0.4	2.15	0.00	1.00	0.48	0.00	0.20	0.07	0.27	0.69	0.00	0.00	0.01	0.19
43.7	0.4	2.08	0.00	1.00	0.48	0.00	0.20	0.08	0.27	0.94	0.00	0.00	0.02	0.25
43.9	0.6	1.98	0.00	1.00	0.81	0.00	0.25	0.11	0.33	1.00	0.00	0.00	0.03	0.33
44.0	0.7	1.64	1.00	0.00	0.95	0.00	0.35	0.24	0.47	1.00	0.00	0.00	0.08	0.47
44.2	1.0	0.98	1.00	0.13	1.00	0.22	0.50	0.64	0.67	1.00	0.13	0.22	0.32	0.67
44.4	1.1	0.84	1.00	0.00	1.00	0.39	0.53	0.75	0.73	1.00	0.00	0.39	0.40	0.73
44.6	0.8	0.76	1.00	0.00	0.98	0.48	0.40	0.69	0.53	1.00	0.00	0.48	0.33	0.53
44.8	0.5	0.56	0.00	0.00	0.61	0.74	0.25	0.88	0.33	1.00	0.00	0.45	0.24	0.33
45.0	0.4	0.15	0.00	0.00	0.48	0.94	0.20	1.00	0.27	0.98	0.00	0.46	0.20	0.29
AVERAGE			0.78	0.32	0.96	0.45	0.48	0.84	0.62	0.92	0.16	0.40	0.31	0.58
10 cfs														
42.8	0.3	0.00	0.00	0.00	0.37	0.96	0.18	1.00	0.20	0.81	0.00	0.36	0.18	0.16
44.0	0.4	0.06	0.00	0.00	0.48	0.98	0.20	1.00	0.27	0.92	0.00	0.46	0.20	0.22
46.0	0.5	0.05	0.00	0.00	0.61	0.98	0.25	1.00	0.33	0.91	0.00	0.60	0.25	0.27
46.8	0.6	0.02	0.00	0.00	0.73	0.99	0.30	1.00	0.40	0.21	0.00	0.73	0.30	0.32
48.7	0.8	0.03	0.00	0.00	0.73	0.98	0.30	1.00	0.40	0.81	0.00	0.73	0.30	0.32
47.5	0.7	0.10	1.00	0.00	0.85	0.98	0.35	1.00	0.47	0.84	0.00	0.82	0.35	0.38
48.0	0.8	0.24	1.00	0.00	1.00	0.90	0.45	1.00	0.60	0.90	0.00	0.90	0.45	0.64
48.5	0.8	0.57	1.00	0.00	1.00	0.73	0.45	0.88	0.60	1.00	0.00	0.73	0.40	0.60
48.8	0.9	0.70	1.00	0.00	1.00	0.58	0.45	0.85	0.60	1.00	0.00	0.58	0.38	0.60
51.0	1.1	0.86	1.00	0.00	1.00	0.37	0.58	0.73	0.73	1.00	0.00	0.37	0.40	0.73
52.5	1.1	0.98	1.00	0.00	1.00	0.27	0.55	0.73	0.73	1.00	0.00	0.27	0.40	0.73
54.0	1.3	0.91	1.00	0.00	1.00	0.43	0.65	0.77	0.87	1.00	0.00	0.43	0.50	0.87
55.5	1.2	0.14	1.00	0.00	1.00	0.94	0.95	1.00	0.97	0.98	0.00	0.94	0.95	0.74
57.3	0.5	0.69	0.00	0.00	0.61	0.58	0.25	0.98	0.33	1.00	0.00	0.58	0.25	0.33
57.0	0.4	0.20	0.00	0.00	0.49	0.92	0.20	1.00	0.27	0.96	0.00	0.46	0.20	0.22
56.3	0.1	0.71	0.00	0.00	0.13	0.53	0.05	0.94	0.07	1.00	0.00	0.07	0.04	0.07
61.0	0.1	0.19	0.00	0.00	0.13	0.54	0.05	0.98	0.07	1.00	0.00	0.07	0.04	0.07
61.5	<0.1		0.00	0.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
63.0	0.2	0.06	0.00	0.00	0.24	0.97	0.10	1.00	0.13	0.83	0.00	0.24	0.10	0.11
64.0	0.4	0.79	1.00	0.00	0.48	0.46	0.20	0.79	0.27	1.00	0.00	0.22	0.15	0.27
65.2	0.7	0.54	1.00	0.00	0.98	0.75	0.35	0.97	0.47	1.00	0.00	0.84	0.34	0.47
66.0	0.8	0.42	1.00	0.00	0.98	0.82	0.40	1.00	0.54	0.97	0.00	0.81	0.40	0.52
67.0	0.5	0.39	0.00	0.00	0.61	0.86	0.25	1.00	0.33	0.95	0.00	0.53	0.25	0.30
68.0	0.3	0.03	0.00	0.00	0.37	0.99	0.15	1.00	0.20	0.91	0.00	0.36	0.15	0.18
68.8	0.1	0.02	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.81	0.00	0.13	0.05	0.05
AVERAGE			0.40	0.00	0.53	0.79	0.29	0.93	0.38	0.91	0.00	0.47	0.27	0.36
5 cfs														
42.8	0.1		0.00	0.00	0.12	1.00	0.06	1.00	0.07	0.90	0.00	0.12	0.05	0.06
44.0	0.2	0.09	0.00	0.00	0.24	0.97	0.10	1.00	0.13	0.83	0.00	0.24	0.10	0.11
46.0	0.4	0.18	0.00	0.00	0.48	0.93	0.20	1.00	0.27	0.47	0.00	0.46	0.20	0.23
46.8	0.6	0.18	0.00	0.00	0.61	0.83	0.25	1.00	0.33	0.67	0.00	0.56	0.25	0.29
48.7	0.4	0.16	0.00	0.00	0.42	0.88	0.20	1.00	0.27	0.84	0.00	0.47	0.20	0.22
47.5	0.7	0.13	1.00	0.00	0.85	0.95	0.35	1.00	0.47	0.88	0.00	0.81	0.35	0.40
48.0	0.7	0.22	1.00	0.00	0.85	0.91	0.35	1.00	0.47	0.86	0.00	0.78	0.35	0.41
48.5	0.7	0.37	1.00	0.00	0.85	0.86	0.35	1.00	0.47	0.95	0.00	0.73	0.34	0.44
48.8	0.8	0.48	1.00	0.00	0.98	0.80	0.40	1.00	0.53	1.00	0.00	0.78	0.40	0.53
51.0	0.8	0.53	1.00	0.00	1.00	0.63	0.45	0.93	0.60	1.00	0.00	0.63	0.42	0.60
52.5	0.8	0.63	1.00	0.00	1.00	0.54	0.45	0.90	0.60	1.00	0.00	0.54	0.41	0.60
54.0	1.2	0.36	1.00	0.00	1.00	0.86	0.60	1.00	0.80	0.94	0.00	0.86	0.60	0.79
55.5	1.1	0.25	1.00	0.00	1.00	0.93	0.55	1.00	0.73	0.90	0.00	0.90	0.55	0.66
57.3	0.9	0.41	1.00	0.00	0.98	0.84	0.45	1.00	0.53	0.98	0.00	0.82	0.45	0.51
57.0	0.2	0.17	0.00	0.00	0.24	0.93	0.10	1.00	0.13	0.97	0.00	0.23	0.10	0.12
63.0	0.0		0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
64.0	0.2	0.45	0.00	0.00	0.24	0.82	0.10	1.00	0.13	0.98	0.00	0.20	0.10	0.12
65.2	0.4	0.81	0.00	0.00	0.48	0.64	0.20	0.81	0.27	1.00	0.00	0.32	0.18	0.27
66.0	0.6	0.52	0.00	0.00	0.73	0.78	0.30	0.98	0.40	1.00	0.00	0.57	0.30	0.40
67.0	0.4	0.30	0.00	0.00	0.48	0.88	0.20	1.00	0.27	0.92	0.00	0.43	0.20	0.24
68.0	0.1	0.20	0.00	0.00	0.13	0.92	0.05	1.00	0.07	0.88	0.00	0.11	0.05	0.06
AVERAGE			0.43	0.00	0.61	0.86	0.27	0.93	0.36	0.91	0.00	0.51	0.26	0.34

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 1
TRANS 3

			HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
	DEPTH	VELOCITY												
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
30 cfs														
12.0	0.8	0.00	0.00	0.00	0.73	0.89	0.30	1.00	0.40	0.81	0.00	0.73	0.30	0.38
13.7	0.9	0.00	1.00	0.00	1.00	0.89	0.46	1.00	0.60	0.81	0.00	0.89	0.46	0.49
13.3	1.3	0.00	1.00	0.00	1.00	0.89	0.66	1.00	0.87	0.81	0.00	0.89	0.66	0.70
14.6	1.6	0.11	1.00	0.00	1.00	0.96	0.76	1.00	1.00	0.94	0.00	0.96	0.76	0.94
15.0	1.8	0.06	1.00	0.00	1.00	0.89	0.86	1.00	1.00	0.92	0.00	0.89	0.86	0.92
16.0	1.3	0.27	1.00	0.00	1.00	0.96	0.66	1.00	0.87	0.81	0.00	0.96	0.66	0.70
17.3	1.7	0.34	1.00	0.00	0.86	0.87	0.96	1.00	1.00	0.83	0.00	0.93	0.96	0.93
16.3	1.7	0.00	1.00	0.00	0.86	0.87	0.86	1.00	1.00	1.00	0.00	0.84	0.79	1.00
18.3	1.8	0.04	1.00	0.00	0.79	0.27	0.96	0.67	1.00	1.00	0.00	0.21	0.64	1.00
20.8	1.8	1.57	1.00	0.24	0.87	0.17	0.86	0.27	1.00	1.00	0.24	0.15	0.51	1.00
21.8	1.9	1.06	1.00	0.32	0.79	0.19	0.96	0.54	1.00	1.00	0.32	0.14	0.54	1.00
23.0	2.1	0.83	1.00	0.42	0.62	0.40	1.00	0.75	1.00	1.00	0.00	0.25	0.75	1.00
24.0	2.2	0.62	1.00	0.00	0.48	0.40	1.00	0.75	1.00	1.00	0.00	0.18	0.75	1.00
25.3	2.4	0.69	1.00	0.00	0.38	0.30	1.00	0.88	1.00	1.00	0.00	0.22	0.88	1.00
26.2	2.5	0.49	1.00	0.00	0.30	0.58	1.00	0.88	1.00	1.00	0.00	0.17	0.88	1.00
24.5	1.9	0.75	1.00	0.00	0.79	0.40	0.86	0.80	1.00	1.00	0.00	0.32	0.79	1.00
27.5	2.5	0.64	1.00	0.00	0.71	0.75	1.00	0.97	1.00	1.00	0.00	0.53	0.97	1.00
28.8	2.2	0.36	1.00	0.00	0.54	0.28	1.00	1.00	1.00	0.94	0.00	0.47	1.00	0.94
29.2	2.3	0.26	1.00	0.00	0.54	0.28	1.00	1.00	1.00	0.94	0.00	0.47	1.00	0.94
30.0	1.3	0.21	1.00	0.00	1.00	0.27	0.86	1.00	0.87	0.83	0.00	0.97	0.86	0.90
30.7	1.8	0.21	1.00	0.00	0.87	0.40	1.00	1.00	1.00	1.00	0.00	0.60	1.00	0.99
32.0	1.8	0.00	1.00	0.00	1.00	0.39	0.75	1.00	1.00	0.81	0.00	0.88	0.75	0.81
32.0	1.4	0.04	1.00	0.00	1.00	0.89	0.70	1.00	0.93	0.92	0.00	0.89	0.70	0.79
34.5	1.1	0.04	1.00	0.00	1.00	0.28	0.56	1.00	0.73	0.83	0.00	0.66	0.56	0.62
36.8	1.4	0.00	1.00	0.00	1.00	0.89	0.75	1.00	0.93	0.81	0.00	0.89	0.75	0.79
37.0	0.3	0.00	0.00	0.00	0.27	1.00	0.15	1.00	0.20	0.90	0.00	0.27	0.15	0.19
36.2	0.6	0.00	0.00	0.00	0.73	0.89	0.30	1.00	0.40	0.81	0.00	0.73	0.30	0.38
38.8	1.0	0.53	1.00	0.00	1.00	0.89	0.56	1.00	0.67	0.81	0.00	0.89	0.56	0.64
39.8	1.0	0.00	1.00	0.00	1.00	0.89	0.56	1.00	0.67	0.81	0.00	0.89	0.56	0.64
40.5	0.7	0.00	1.00	0.00	0.86	0.89	0.36	1.00	0.47	0.81	0.00	0.84	0.36	0.39
41.0	0.3	0.00	0.00	0.00	0.27	0.89	0.15	1.00	0.20	0.81	0.00	0.27	0.15	0.19
AVERAGE			0.87	0.02	0.79	0.73	0.72	0.93	0.83	0.88	0.02	0.65	0.65	0.76
10 cfs														
12.0	0.3	0.00	0.00	0.00	0.27	0.89	0.15	1.00	0.20	0.81	0.00	0.36	0.15	0.19
13.7	0.6	0.00	0.00	0.00	0.73	0.89	0.30	1.00	0.40	0.81	0.00	0.73	0.30	0.38
13.3	1.0	0.00	1.00	0.00	1.00	0.89	0.50	1.00	0.67	0.81	0.00	0.89	0.50	0.54
14.6	1.2	0.00	1.00	0.00	1.00	0.89	0.66	1.00	0.80	0.81	0.00	0.89	0.66	0.65
15.0	1.2	0.00	1.00	0.00	1.00	0.89	0.66	1.00	0.80	0.81	0.00	0.89	0.66	0.65
16.0	1.2	0.00	1.00	0.00	1.00	0.89	0.66	1.00	0.80	0.81	0.00	0.89	0.66	0.65
17.3	1.4	0.06	1.00	0.00	1.00	0.96	0.76	1.00	0.93	0.92	0.00	0.96	0.76	0.77
16.3	1.4	0.06	1.00	0.00	1.00	0.89	0.76	1.00	0.93	0.92	0.00	0.89	0.76	0.77
18.3	1.5	0.17	1.00	0.00	1.00	0.92	0.76	1.00	1.00	0.97	0.00	0.92	0.76	0.97
20.8	1.5	0.29	1.00	0.00	1.00	0.89	0.76	1.00	1.00	0.92	0.00	0.89	0.76	0.92
21.8	1.4	0.00	1.00	0.00	1.00	0.89	0.76	1.00	0.93	1.00	0.00	0.89	0.76	1.00
23.0	1.5	0.30	1.00	0.00	1.00	0.92	0.76	1.00	1.00	0.97	0.00	0.92	0.76	0.97
24.0	0.9	0.00	1.00	0.00	0.71	0.89	1.00	1.00	1.00	1.00	0.00	0.81	1.00	1.00
25.3	2.0	0.20	1.00	0.00	0.71	0.89	1.00	1.00	1.00	0.92	0.00	0.83	1.00	0.92
26.2	1.9	0.13	1.00	0.00	1.00	0.96	0.86	1.00	1.00	0.96	0.00	0.96	0.86	0.96
27.5	1.9	0.06	1.00	0.00	0.97	0.89	0.86	1.00	1.00	0.92	0.00	0.97	0.86	0.92
28.8	1.9	0.00	1.00	0.00	1.00	0.89	0.86	1.00	1.00	0.91	0.00	0.96	0.86	0.91
29.2	1.9	0.00	1.00	0.00	1.00	0.89	0.86	1.00	1.00	0.91	0.00	0.96	0.86	0.91
30.0	0.9	0.04	1.00	0.00	1.00	0.89	0.46	1.00	0.93	0.92	0.00	0.98	0.46	0.49
30.7	1.2	0.00	1.00	0.00	1.00	0.89	0.60	1.00	0.80	0.81	0.00	0.89	0.60	0.65
32.0	1.1	0.00	1.00	0.00	1.00	0.89	0.56	1.00	0.73	0.81	0.00	0.89	0.56	0.59
32.0	0.8	0.00	1.00	0.00	0.86	0.89	0.46	1.00	0.60	0.81	0.00	0.89	0.46	0.49
34.5	0.7	0.00	1.00	0.00	0.86	0.89	0.36	1.00	0.47	0.81	0.00	0.84	0.36	0.39
36.8	1.1	0.00	1.00	0.00	1.00	0.89	0.56	1.00	0.73	0.81	0.00	0.89	0.56	0.59
37.0	0.2	0.03	0.00	0.00	0.24	0.89	0.13	1.00	0.13	0.91	0.00	0.24	0.13	0.11
36.2	0.3	0.00	0.00	0.00	0.27	0.89	0.15	1.00	0.20	0.81	0.00	0.36	0.15	0.19
38.8	0.7	0.00	1.00	0.00	0.86	0.89	0.36	1.00	0.47	0.81	0.00	0.84	0.36	0.39
39.8	0.8	0.00	1.00	0.00	0.73	0.89	0.30	1.00	0.40	0.81	0.00	0.73	0.30	0.32
40.5	0.3	0.00	0.00	0.00	0.27	0.89	0.15	1.00	0.20	0.81	0.00	0.36	0.15	0.19
41.0	0.1	0.00	0.00	0.00	0.12	0.89	0.06	1.00	0.07	0.81	0.00	0.12	0.06	0.06
AVERAGE			0.77	0.00	0.82	0.89	0.64	1.00	0.71	0.84	0.00	0.79	0.64	0.60
5 cfs														
12.7	0.4	0.00	0.00	0.00	0.43	0.89	0.20	1.00	0.27	0.81	0.00	0.49	0.20	0.22
13.3	0.8	0.00	1.00	0.00	0.86	0.89	0.40	1.00	0.53	0.81	0.00	0.86	0.40	0.43
14.6	1.0	0.00	1.00	0.00	1.00	0.89	0.50	1.00	0.67	0.81	0.00	0.89	0.50	0.54
15.0	1.1	0.00	1.00	0.00	1.00	0.89	0.56	1.00	0.73	0.81	0.00	0.89	0.56	0.59
16.0	0.9	0.06	1.00	0.00	0.98	0.97	0.40	1.00	0.53	0.83	0.00	0.96	0.40	0.44
17.3	1.0	0.13	1.00	0.00	1.00	0.96	0.50	1.00	0.67	0.96	0.00	0.96	0.50	0.64
16.3	1.0	0.17	1.00	0.00	1.00	0.89	0.50	1.00	0.67	0.97	0.00	0.93	0.50	0.75
18.3	1.1	0.15	1.00	0.00	1.00	0.94	0.70	1.00	0.93	0.98	0.00	0.94	0.70	0.90
20.8	1.4	0.29	1.00	0.00	1.00	0.89	0.70	1.00	0.93	0.92	0.00	0.89	0.70	0.92
21.8	1.4	0.37	1.00	0.00	1.00	0.85	0.70	1.00	0.93	0.89	0.00	0.85	0.70	0.89
23.0	1.2	0.15	1.00	0.00	0.96	0.89	0.80	1.00	1.00	0.94	0.00	0.94	0.80	0.94
24.0	1.8	0.34	1.00	0.00	0.87	0.89	0.80	1.00	1.00	0.94	0.00	0.75	0.80	0.94
25.3	1.8	0.20	1.00	0.00	0.79	0.89	0.96	1.00	1.00	0.94	0.00	0.79	0.96	0.94
26.2	1.9	0.20	1.00	0.00	0.79	0.92	0.86	1.00	1.00	0.98	0.00	0.73	0.96	0.98
27.5	1.4	0.20	1.00	0.00	1.00	0.89	0.70	1.00	0.93	0.92	0.00	0.89	0.70	0.92
28.8	1.4	0.20	1.00	0.00	1.00	0.89	0.70	1.00	0.93	0.92	0.00	0.89	0.70	0.92
29.2	1.4	0.15	1.00	0.00	1.00	0.94	0.70	1.00	0.93	0.98	0.00	0.94	0.70	0.98
30.0	0.8	0.06	1.00	0.00	1.00	0.89	0.40	1.00	0.53	0.92	0.00	0.96	0.40	0.44
30.7	1.7	0.00	1.00	0.00	0.96	0.89	0.86	1.00	1.00	0.91	0.00	0.94	0.86	0.91
32.0	1.6	0.00	1.00	0.00	0.98	0.89	0.80	1.00	1.00	0.88	0.00	0.89	0.80	0.88
32.0	1.2	0.00	1.00	0.00	1.00	0.89	0.60	1.00	0.80	0.81	0.00	0.89	0.60	0.65
34.5	0.9	0.00	1.00	0.00	0.73	0.89	0.40	1.00	0.53	0.81	0.00	0.73	0.40	0.43
36.8	0.8	0.00	1.00	0.00	1.00	0.89	0.46	1.00	0.60	0.81	0.00	0.89	0.46	0.49
37.0	0.5	0.00	0.00	0.00	0.53	0.89	0.26	1.00	0.27	0.81	0.00	0.53	0.26	0.27
36.2	0.5	0.00	0.00	0.00	0.51	0.89	0.26	1.00	0.33	0.81	0.00	0.49	0.26	0.27
38.8	0.5	0.00	0.00	0.00	0.51	0.89	0.26	1.00	0.33	0.81	0.00	0.49	0.26	0.27
39.8	0.5	0.00	0.00	0.00	0.51	0.89	0.26	1.00	0.33	0.81	0.00	0.49	0.26	0.27
40.5	0.1	0.00	0.00	0.00	0.12	0.89	0.06	1.00	0.07	0.81	0.00	0.12	0.06	0.06
AVERAGE			0.11	0.79	0.00	0.85	0.90	0.54	1.00	0.69	0.84	0.00	0.91	0.64	0.53

J-728 Alameda Creek

Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 1

TRANS 4

			HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
	DEPTH	VELOCITY	SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
10 cfs														
10.0	0.7	0.53	1.00	0.99	0.46	0.99	0.34	1.00	0.47	0.81	0.00	0.84	0.36	0.39
90.0	0.3	0.53	0.00	0.99	0.81	0.99	0.25	1.00	0.33	0.81	0.00	0.90	0.26	0.27
81.0	0.3	0.00	0.00	0.00	0.37	0.00	0.15	1.00	0.20	0.81	0.00	0.36	0.15	0.18
24.0	0.2	0.53	0.00	0.00	0.24	0.00	0.10	1.00	0.13	0.81	0.00	0.24	0.10	0.11
57.0	0.1	0.00	0.00	0.00	0.10	1.00	0.06	1.00	0.07	0.80	0.00	0.13	0.06	0.06
98.0	0.4	0.39	0.00	0.00	0.48	0.84	0.20	1.00	0.27	0.88	0.00	0.41	0.20	0.24
29.0	0.4	1.06	0.00	0.25	0.48	0.17	0.20	0.37	0.27	1.00	0.00	0.08	0.11	0.27
31.0	0.5	0.53	0.00	0.37	0.60	0.99	0.15	1.00	0.20	0.81	0.00	0.36	0.15	0.18
30.0	0.4	0.74	0.00	0.00	0.48	0.52	0.20	0.82	0.27	1.00	0.00	0.25	0.19	0.27
32.0	0.4	1.06	0.00	0.56	0.48	0.19	0.20	0.44	0.27	1.00	0.00	0.09	0.09	0.27
36.0	0.4	0.53	0.00	0.00	0.48	0.99	0.20	1.00	0.27	0.81	0.00	0.40	0.20	0.22
38.0	0.8	0.53	1.00	0.00	1.00	0.79	0.46	0.97	0.60	1.00	0.00	0.79	0.44	0.60
34.0	0.7	0.31	1.00	0.00	0.88	0.00	0.36	1.00	0.47	0.88	0.00	0.76	0.36	0.41
39.0	0.8	1.18	1.00	0.48	0.88	0.10	0.40	0.49	0.53	1.00	0.48	0.12	0.20	0.53
40.0	0.9	1.15	1.00	0.35	0.88	0.14	0.40	0.51	0.53	1.00	0.35	0.14	0.21	0.53
41.0	0.8	1.01	1.00	0.15	0.88	0.25	0.40	0.62	0.53	1.00	0.15	0.19	0.25	0.53
42.0	1.0	0.42	1.00	0.00	1.00	0.63	0.50	1.00	0.67	0.97	0.00	0.82	0.50	0.65
43.0	1.2	0.38	1.00	0.00	1.00	0.98	0.60	1.00	0.80	0.94	0.00	0.88	0.60	0.75
44.5	1.3	0.14	1.00	0.00	1.00	0.94	0.80	1.00	0.80	0.88	0.00	0.94	0.80	0.68
46.0	1.1	0.15	1.00	0.00	1.00	0.94	0.66	1.00	0.73	0.88	0.00	0.94	0.66	0.63
48.0	1.0	0.27	1.00	0.00	1.00	0.86	0.50	1.00	0.67	0.88	0.00	0.86	0.50	0.63
49.5	1.1	0.63	1.00	0.05	1.00	0.28	0.56	0.48	0.73	1.00	0.05	0.26	0.37	0.73
51.0	1.0	1.25	1.00	0.60	1.00	0.10	0.50	0.44	0.67	1.00	0.50	0.10	0.22	0.67
52.0	1.0	0.35	1.00	0.00	1.00	0.88	0.50	1.00	0.67	0.94	0.00	0.90	0.50	0.63
54.2	1.0	0.13	1.00	0.00	1.00	0.95	0.50	1.00	0.67	0.88	0.00	0.96	0.50	0.57
56.0	0.5	0.15	0.00	0.00	0.91	0.94	0.25	1.00	0.33	0.99	0.00	0.87	0.25	0.29
58.0	0.4	0.37	0.00	0.00	0.48	0.85	0.20	1.00	0.27	0.88	0.00	0.82	0.20	0.25
60.0	0.3	0.17	0.00	0.00	0.37	0.93	0.15	1.00	0.20	0.97	0.00	0.94	0.15	0.17
AVERAGE			0.54	0.18	0.73	0.72	0.34	0.86	0.45	0.91	0.06	0.48	0.29	0.42
3 cfs														
10.7	0.2	0.03	0.00	0.00	0.24	0.99	0.10	1.00	0.13	0.81	0.00	0.24	0.10	0.11
10.0	0.8	0.03	0.00	0.00	0.73	0.99	0.30	1.00	0.40	0.81	0.00	0.73	0.30	0.32
20.0	0.5	0.03	0.00	0.00	0.61	0.99	0.25	1.00	0.33	0.81	0.00	0.80	0.26	0.27
21.5	0.2	0.03	0.00	0.00	0.24	0.99	0.10	1.00	0.13	0.81	0.00	0.24	0.10	0.11
26.0	0.2	0.10	0.00	0.00	0.24	0.96	0.10	1.00	0.13	0.84	0.00	0.23	0.10	0.11
29.0	0.3	0.62	0.00	0.00	0.37	0.48	0.15	0.91	0.20	1.00	0.00	0.24	0.14	0.20
20.0	0.3	0.93	0.00	0.00	0.37	0.28	0.15	0.68	0.20	1.00	0.00	0.18	0.10	0.20
35.0	0.2	0.14	0.00	0.00	0.24	0.94	0.10	1.00	0.13	0.88	0.00	0.23	0.10	0.11
36.0	0.5	0.36	0.00	0.00	0.61	0.86	0.25	1.00	0.33	0.88	0.00	0.82	0.26	0.32
38.0	0.5	0.49	0.00	0.00	0.61	0.80	0.25	1.00	0.33	1.00	0.00	0.48	0.25	0.33
39.0	0.8	0.49	0.00	0.00	0.73	0.80	0.30	1.00	0.40	1.00	0.00	0.54	0.30	0.40
40.0	0.7	0.47	1.00	0.00	0.85	0.81	0.36	1.00	0.47	0.88	0.00	0.68	0.35	0.44
41.0	0.7	0.68	1.00	0.00	0.85	0.57	0.36	0.98	0.47	1.00	0.00	0.48	0.34	0.47
42.0	0.9	0.65	1.00	0.00	1.00	0.62	0.45	0.88	0.60	1.00	0.00	0.62	0.40	0.60
43.0	1.1	0.27	1.00	0.00	1.00	0.88	0.56	1.00	0.73	0.91	0.00	0.80	0.56	0.67
44.5	1.0	0.02	1.00	0.00	1.00	0.98	0.50	1.00	0.73	0.81	0.00	0.80	0.50	0.59
46.0	1.0	0.03	1.00	0.00	1.00	0.96	0.50	1.00	0.67	0.81	0.00	0.80	0.50	0.54
48.0	1.0	0.15	1.00	0.00	1.00	0.94	0.50	1.00	0.67	0.88	0.00	0.84	0.50	0.57
49.5	1.0	0.39	1.00	0.00	1.00	0.84	0.50	1.00	0.67	0.96	0.00	0.84	0.50	0.64
51.0	0.9	0.44	1.00	0.00	1.00	0.80	0.45	0.98	0.60	1.00	0.00	0.80	0.38	0.60
52.0	1.0	0.25	1.00	0.00	1.00	0.90	0.50	1.00	0.67	0.90	0.00	0.90	0.50	0.60
54.5	1.0	0.05	1.00	0.00	1.00	0.98	0.50	1.00	0.67	0.92	0.00	0.98	0.50	0.56
55.9	0.4	0.15	0.00	0.00	0.48	0.94	0.20	1.00	0.27	0.88	0.00	0.46	0.20	0.23
58.0	0.3	0.13	0.00	0.00	0.37	0.95	0.15	1.00	0.20	0.88	0.00	0.35	0.15	0.17
59.0	0.1		0.00	0.00	0.12	1.00	0.06	1.00	0.07	0.80	0.00	0.12	0.06	0.06
AVERAGE			0.44	0.00	0.67	0.85	0.31	0.97	0.41	0.90	0.00	0.56	0.30	0.37

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes

REACH 1
TRANS 5

			HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
	DEPTH	VELOCITY	SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
10 cfs														
15.8	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
17.0	0.7	0.06	1.00	0.00	0.95	0.97	0.95	1.00	0.97	0.93	0.00	0.93	0.95	0.90
18.5	1.3	0.09	1.00	0.00	1.00	0.97	0.95	1.00	0.97	0.93	0.00	0.97	0.95	0.73
20.0	1.5	0.06	1.00	0.00	1.00	0.96	0.75	1.00	1.00	0.84	0.00	0.96	0.75	0.84
21.5	1.3	0.10	1.00	0.00	0.79	0.93	0.95	1.00	1.00	0.97	0.00	0.79	0.95	0.97
23.0	1.3	0.10	1.00	0.00	0.79	0.94	0.95	1.00	1.00	0.96	0.00	0.74	0.95	0.96
24.5	1.7	0.26	1.00	0.00	0.95	0.84	0.95	1.00	1.00	0.98	0.00	0.80	0.95	0.98
26.5	1.5	0.45	1.00	0.00	1.00	0.82	0.75	1.00	1.00	0.98	0.00	0.82	0.75	0.98
27.0	1.2	0.64	1.00	0.00	1.00	0.93	0.80	0.98	0.80	1.00	0.00	0.93	0.64	0.80
28.5	1.0	0.81	1.00	0.00	1.00	0.43	0.50	0.79	0.67	1.00	0.00	0.43	0.39	0.67
30.0	0.8	0.98	1.00	0.00	1.00	0.34	0.45	0.71	0.80	1.00	0.00	0.34	0.32	0.80
31.5	0.8	0.74	1.00	0.00	0.98	0.53	0.40	0.82	0.53	1.00	0.00	0.50	0.33	0.53
33.0	0.7	0.57	1.00	0.00	0.85	0.73	0.35	0.95	0.47	1.00	0.00	0.62	0.33	0.47
34.5	0.7	0.38	1.00	0.00	0.95	0.85	0.35	1.00	0.47	0.95	0.00	0.73	0.35	0.44
36.0	0.7	0.35	1.00	0.00	0.95	0.90	0.35	1.00	0.47	0.84	0.00	0.74	0.35	0.44
37.5	0.8	0.25	0.00	0.00	0.73	0.99	0.30	1.00	0.40	0.84	0.00	0.83	0.30	0.38
39.0	0.8	0.25	0.00	0.00	0.73	0.90	0.30	1.00	0.40	0.90	0.00	0.86	0.30	0.38
40.5	0.4	0.06	0.00	0.00	0.45	0.95	0.20	1.00	0.27	0.92	0.00	0.45	0.20	0.25
41.0	0.2	0.14	0.00	0.00	0.27	0.94	0.15	1.00	0.80	0.98	0.00	0.35	0.15	0.17
AVERAGE			0.74	0.00	0.81	0.81	0.49	0.95	0.81	0.92	0.00	0.63	0.47	0.57
5 cfs														
17.0	0.5	0.03	0.00	0.00	0.61	0.99	0.25	1.00	0.33	0.91	0.00	0.60	0.25	0.27
18.5	1.0	0.03	1.00	0.00	1.00	0.98	0.50	1.00	0.67	0.91	0.00	0.98	0.50	0.54
20.0	1.5	0.03	1.00	0.00	1.00	0.98	0.75	1.00	1.00	0.91	0.00	0.98	0.75	0.91
21.5	1.7	0.13	1.00	0.00	0.95	0.95	0.95	1.00	1.00	0.95	0.00	0.90	0.95	0.95
23.0	1.3	0.14	1.00	0.00	0.87	0.94	0.90	1.00	1.00	0.98	0.00	0.83	0.90	0.98
24.5	1.8	0.22	1.00	0.00	1.00	0.91	0.80	1.00	1.00	0.98	0.00	0.91	0.80	0.98
26.5	1.2	0.20	1.00	0.00	1.00	0.90	0.65	1.00	0.87	0.98	0.00	0.90	0.65	0.76
27.0	1.0	0.30	1.00	0.00	1.00	0.98	0.50	1.00	0.67	0.92	0.00	0.98	0.50	0.61
28.5	0.9	0.57	1.00	0.00	1.00	0.73	0.45	0.95	0.80	1.00	0.00	0.73	0.43	0.80
30.0	0.8	0.44	1.00	0.00	0.98	0.92	0.40	1.00	0.53	0.98	0.00	0.90	0.40	0.52
31.5	0.7	0.42	1.00	0.00	0.98	0.89	0.35	1.00	0.47	0.97	0.00	0.71	0.35	0.46
33.0	0.6	0.37	0.00	0.00	0.73	0.95	0.30	1.00	0.40	0.95	0.00	0.62	0.30	0.38
34.5	0.6	0.08	0.00	0.00	0.73	0.97	0.30	1.00	0.40	0.93	0.00	0.71	0.30	0.33
36.0	0.5	0.08	0.00	0.00	0.61	0.97	0.25	1.00	0.33	0.92	0.00	0.59	0.25	0.29
37.5	0.5	0.10	0.00	0.00	0.61	0.98	0.25	1.00	0.33	0.84	0.00	0.59	0.25	0.28
39.0	0.4	0.53	0.00	0.00	0.48	0.39	0.20	1.00	0.27	0.81	0.00	0.46	0.20	0.22
40.0	0.2	0.03	0.00	0.00	0.34	0.98	0.10	1.00	0.13	0.91	0.00	0.34	0.10	0.11
41.0	0.1	0.03	0.00	0.00	0.13	0.98	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
AVERAGE			0.56	0.00	0.77	0.93	0.44	1.00	0.56	0.97	0.00	0.79	0.43	0.49

Habitat suitability index ranges for depth and velocity at three flow regimes.

TABLE 1
Page 1

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
CHART	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWNING	FRY	JUV	ADULT
30-cm														

J-725 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes

REACH:
TRANS 7

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								SUMMED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
25 cfs														
37.2	0.2	0.52	0.40	0.28	0.91	0.48	0.55	0.84	0.72	0.97	0.68	1.39	0.99	0.7
36.2	0.2	0.25	0.40	0.28	0.91	0.97	0.55	0.84	0.96	0.97	0.68	1.88	0.99	0.93
35.2	0.2	0.02	0.40	0.28	0.91	0.99	0.55	0.84	0.96	0.97	0.68	1.9	0.99	0.93
34.2	0.2	0.02	0.40	0.28	0.91	0.99	0.55	0.84	0.96	0.97	0.68	1.9	0.99	0.93
33.2	0.2	0.4	0.40	0.28	0.91	0.92	0.55	0.84	0.96	0.97	0.68	1.83	0.99	0.93
32.2	0.2	0.4	0.40	0.28	0.91	0.92	0.55	0.84	0.96	0.97	0.68	1.83	0.99	0.93
31.2	0.2	0.28	0.40	0.28	0.91	0.77	0.55	0.84	0.96	0.97	0.68	1.68	0.99	0.93
30.2	0.2	0.27	0.40	0.28	0.91	0.76	0.55	0.84	0.96	0.97	0.68	1.67	0.99	0.93
29.2	0.2	0.33	0.40	0.28	0.91	0.83	0.55	0.84	0.96	0.97	0.68	1.74	0.99	0.93
28.2	0.2	0.27	0.40	0.28	0.91	0.76	0.55	0.84	0.96	0.97	0.68	1.67	0.99	0.93
27.2	0.2	0.27	0.40	0.28	0.91	0.76	0.55	0.84	0.96	0.97	0.68	1.67	0.99	0.93
26.2	0.2	0.31	0.40	0.28	0.91	0.81	0.55	0.84	0.96	0.97	0.68	1.72	0.99	0.93
25.2	0.2	0.23	0.40	0.28	0.91	0.72	0.55	0.84	0.96	0.97	0.68	1.63	0.99	0.93
24.2	0.2	0.23	0.40	0.28	0.91	0.72	0.55	0.84	0.96	0.97	0.68	1.63	0.99	0.93
23.2	0.2	0.23	0.40	0.28	0.91	0.72	0.55	0.84	0.96	0.97	0.68	1.63	0.99	0.93
22.2	0.2	0.23	0.40	0.28	0.91	0.72	0.55	0.84	0.96	0.97	0.68	1.63	0.99	0.93
21.2	0.2	0.23	0.40	0.28	0.91	0.72	0.55	0.84	0.96	0.97	0.68	1.63	0.99	0.93
20.2	0.2	0.23	0.40	0.28	0.91	0.72	0.55	0.84	0.96	0.97	0.68	1.63	0.99	0.93
AVERAGE			0.40	0.28	0.91	0.83	0.55	0.84	0.96	0.97	0.68	1.74	0.99	0.93
50 cfs														
42.1	0.1	0.35	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.32	0.84	0.53
41.1	0.1	0.77	0.25	0.28	0.72	0.96	0.34	0.9	0.57	0.96	0.53	1.68	0.84	0.53
40.1	0.1	0.43	0.25	0.28	0.72	0.85	0.34	0.9	0.57	0.96	0.53	1.81	0.84	0.53
39.1	0.1	0.65	0.25	0.28	0.72	0.8	0.34	0.9	0.57	0.96	0.53	1.76	0.84	0.53
38.1	0.1	0.6	0.25	0.28	0.72	0.8	0.34	0.9	0.57	0.96	0.53	1.64	0.84	0.53
37.1	0.1	0.25	0.25	0.28	0.72	0.15	0.34	0.9	0.57	0.96	0.53	1.19	0.84	0.53
36.1	0.1	0.25	0.25	0.28	0.72	0.15	0.34	0.9	0.57	0.96	0.53	1.19	0.84	0.53
35.1	0.1	0.66	0.25	0.28	0.72	0.8	0.34	0.9	0.57	0.96	0.53	1.64	0.84	0.53
34.1	0.1	0.47	0.25	0.28	0.72	0.58	0.34	0.9	0.57	0.96	0.53	1.42	0.84	0.53
33.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
32.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
31.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
30.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
29.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
28.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
27.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
26.1	0.1	0.49	0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
AVERAGE			0.25	0.28	0.72	0.6	0.34	0.9	0.57	0.96	0.53	1.44	0.84	0.53
75 cfs														
48.0	0.2	0.32	0.35	0.28	0.84	0.89	0.47	0.8	0.73	0.92	0.63	1.73	1.27	0.65
47.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
46.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
45.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
44.0	0.2	0.27	0.35	0.28	0.84	0.74	0.47	0.8	0.73	0.92	0.63	1.58	1.27	0.65
43.0	0.2	0.27	0.35	0.28	0.84	0.74	0.47	0.8	0.73	0.92	0.63	1.58	1.27	0.65
42.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
41.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
40.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
39.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
38.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
37.0	0.2	0.28	0.35	0.28	0.84	0.75	0.47	0.8	0.73	0.92	0.63	1.59	1.27	0.65
AVERAGE			0.35	0.28	0.84	0.77	0.47	0.8	0.73	0.92	0.63	1.61	1.27	0.65

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 1
TRANS 8

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
10 cfs														
0.0	0.1	0.02	0.00	0.00	0.13	0.98	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
13.0	0.4	0.04	0.00	0.00	0.40	0.91	0.20	1.00	0.27	0.89	0.00	0.44	0.20	0.24
13.7	0.5	0.42	0.00	0.00	0.73	0.62	0.30	1.00	0.40	0.67	0.00	0.81	0.30	0.36
15.5	0.5	0.26	1.00	0.00	1.00	0.98	0.45	1.00	0.60	0.86	0.00	0.98	0.45	0.54
17.9	1.0	0.40	1.00	0.00	1.00	0.94	0.50	1.00	0.67	0.95	0.00	0.94	0.50	0.64
19.0	1.0	0.58	1.00	0.00	1.00	0.89	0.50	0.83	0.67	1.00	0.00	0.89	0.47	0.67
20.5	1.0	0.47	1.00	0.00	1.00	0.91	0.50	1.00	0.67	0.99	0.00	0.91	0.50	0.66
21.8	0.9	0.37	1.00	0.00	0.98	0.98	0.40	1.00	0.53	0.91	0.00	0.97	0.40	0.46
22.5	0.8	1.88	0.00	1.00	0.73	0.00	0.30	0.28	0.40	1.00	0.00	0.00	0.09	0.40
23.5	0.5	1.74	0.00	1.00	0.61	0.00	0.25	0.19	0.33	1.00	0.00	0.00	0.04	0.33
25.5	0.5	1.79	0.00	1.00	0.61	0.00	0.25	0.18	0.33	1.00	0.00	0.00	0.04	0.33
26.0	0.4	1.88	0.00	1.00	0.49	0.00	0.20	0.13	0.27	1.00	0.00	0.00	0.03	0.27
26.6	0.2	1.83	0.00	1.00	0.24	0.00	0.10	0.21	0.13	1.00	0.00	0.00	0.02	0.13
28.3	0.4	1.13	0.00	0.30	0.49	0.15	0.20	0.53	0.27	1.00	0.00	0.07	0.11	0.27
30.7	0.6	0.53	0.00	0.00	0.81	0.78	0.25	0.97	0.33	1.00	0.00	0.46	0.24	0.33
32.0	0.5	0.48	0.00	0.00	0.61	0.81	0.25	1.00	0.33	0.98	0.00	0.49	0.25	0.32
33.0	0.4	0.53	0.00	0.00	0.46	0.78	0.20	0.97	0.27	1.00	0.00	0.37	0.19	0.27
34.0	0.2	0.84	0.00	0.00	0.24	0.38	0.10	0.74	0.13	1.00	0.00	0.09	0.07	0.13
36.0	0.2	1.06	0.00	0.21	0.24	0.19	0.10	0.54	0.13	1.00	0.00	0.04	0.05	0.13
36.3	+0.1	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
38.5	0.3	0.08	0.00	0.00	0.37	0.97	0.15	1.00	0.20	0.82	0.00	0.36	0.15	0.17
41.0	0.5	0.59	0.00	0.00	0.61	0.88	0.25	0.93	0.33	1.00	0.00	0.42	0.23	0.33
42.5	0.3	2.03	0.00	1.00	0.61	0.00	0.25	0.09	0.33	0.94	0.00	0.00	0.02	0.31
44.0	0.5	2.11	0.00	1.00	0.61	0.00	0.25	0.09	0.33	0.79	0.00	0.00	0.02	0.26
45.7	0.3	2.27	0.00	1.00	0.37	0.00	0.15	0.02	0.20	0.25	0.00	0.00	0.00	0.05
46.4	0.4	2.02	0.00	1.00	0.49	0.00	0.20	0.09	0.27	0.34	0.00	0.00	0.02	0.09
47.0	0.5	1.42	0.00	0.71	0.61	0.04	0.25	0.22	0.33	1.00	0.00	0.52	0.09	0.33
AVERAGE			0.19	0.38	0.57	0.47	0.24	0.64	0.32	0.93	0.00	0.39	0.17	0.31
5 cfs														
10.0	0.1	0.05	0.00	0.00	0.49	0.99	0.20	1.00	0.27	0.92	0.00	0.46	0.20	0.22
13.7	0.5	0.10	0.00	0.00	0.73	0.96	0.30	1.00	0.40	0.94	0.00	0.75	0.30	0.34
15.5	1.0	0.13	1.00	0.00	1.00	0.96	0.50	1.00	0.67	0.86	0.00	0.96	0.50	0.57
17.9	0.9	0.21	1.00	0.00	1.00	0.91	0.45	1.00	0.60	0.98	0.00	0.91	0.45	0.53
19.0	0.9	0.13	1.00	0.00	1.00	0.95	0.45	1.00	0.60	0.85	0.00	0.91	0.45	0.51
20.5	0.9	0.25	1.00	0.00	0.98	0.89	0.40	1.00	0.53	0.96	0.00	0.88	0.40	0.48
21.8	0.7	0.98	1.00	0.00	0.85	0.34	0.35	0.71	0.47	1.00	0.00	0.29	0.25	0.47
22.5	0.5	1.49	0.00	0.85	0.61	0.00	0.25	0.25	0.33	1.00	0.00	0.00	0.06	0.33
23.5	0.3	1.64	0.00	1.00	0.37	0.00	0.15	0.21	0.20	1.00	0.00	0.00	0.03	0.20
25.5	0.2	1.49	0.00	0.85	0.24	0.00	0.10	0.25	0.13	1.00	0.00	0.00	0.03	0.13
26.0	0.2	1.47	0.00	0.81	0.24	0.01	0.10	0.27	0.13	1.00	0.00	0.00	0.03	0.13
26.3	0.3	1.32	0.00	0.45	0.37	0.11	0.15	0.46	0.20	1.00	0.00	0.04	0.07	0.20
26.7	0.4	0.02	0.00	0.00	0.49	0.98	0.20	1.00	0.27	0.81	0.00	0.48	0.20	0.22
28.0	0.3	1.06	0.00	0.16	0.37	0.20	0.15	0.62	0.20	1.00	0.00	0.07	0.09	0.20
30.0	0.2	0.92	0.00	0.04	0.24	0.29	0.10	0.98	0.13	1.00	0.00	0.01	0.07	0.13
34.0	0.2	1.22	0.00	0.45	0.24	0.11	0.10	0.46	0.13	1.00	0.00	0.02	0.05	0.13
36.0	0.1	0.00	0.00	0.00	0.13	1.00	0.05	1.00	0.07	0.80	0.00	0.13	0.05	0.06
36.3	0.2	0.05	0.00	0.00	0.24	0.98	0.10	1.00	0.13	0.92	0.00	0.24	0.10	0.11
41.0	0.4	0.66	0.00	0.00	0.49	0.85	0.20	0.98	0.27	1.00	0.00	0.29	0.18	0.27
42.5	0.4	1.52	0.00	0.98	0.49	0.00	0.20	0.34	0.27	1.00	0.00	0.00	0.06	0.27
44.0	0.3	1.24	0.00	1.00	0.37	0.10	0.15	0.45	0.20	1.00	0.00	0.04	0.07	0.20
45.7	0.3	1.52	0.00	0.98	0.24	0.00	0.10	0.22	0.13	1.00	0.00	0.00	0.02	0.13
46.4	0.3	1.11	0.00	0.31	0.37	0.16	0.15	0.64	0.20	1.00	0.00	0.05	0.09	0.20
47.0	0.4	1.10	0.00	0.29	0.49	0.18	0.20	0.56	0.27	1.00	0.00	0.08	0.11	0.27
AVERAGE			0.21	0.31	0.50	0.45	0.21	0.68	0.29	0.94	0.00	0.26	0.10	0.26

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes

REACH 2
TRANS 1

			HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
	DEPTH	VELOCITY	SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
20 cfs														
36.4	0.1	0.03	0.00	0.00	0.13	0.99	0.06	1.00	0.07	0.81	0.00	0.13	0.06	0.06
36.2	0.8	0.76	0.00	0.00	0.87	0.49	0.29	0.80	0.37	1.00	0.00	0.33	0.33	0.37
36.0	0.5	0.79	0.00	0.00	0.61	0.48	0.25	0.79	0.33	1.00	0.00	0.26	0.26	0.33
41.2	0.8	0.74	1.00	0.00	0.98	0.52	0.40	0.82	0.53	1.00	0.00	0.50	0.33	0.53
42.0	0.9	0.96	1.00	0.00	1.00	0.34	0.45	0.71	0.60	1.00	0.00	0.34	0.32	0.60
42.5	1.0	0.83	1.00	0.00	1.00	0.40	0.50	0.75	0.67	1.00	0.00	0.40	0.37	0.67
45.0	1.0	0.96	1.00	0.00	1.00	0.25	0.50	0.64	0.67	1.00	0.00	0.25	0.32	0.67
47.0	0.7	1.09	1.00	0.00	0.95	0.17	0.35	0.57	0.47	1.00	0.00	0.16	0.20	0.47
48.3	1.1	0.83	1.00	0.00	1.00	0.40	0.55	0.75	0.73	1.00	0.00	0.40	0.41	0.73
51.3	1.2	1.20	1.00	0.43	1.00	0.13	0.58	0.47	0.77	1.00	0.43	0.13	0.27	0.77
53.0	1.1	0.80	1.00	0.00	1.00	0.29	0.54	0.88	0.73	1.00	0.00	0.29	0.27	0.73
54.0	1.2	0.78	1.00	0.00	1.00	0.49	0.65	0.80	0.87	1.00	0.00	0.49	0.52	0.87
57.0	0.8	0.59	1.00	0.00	0.91	0.69	0.38	0.93	0.50	1.00	0.00	0.63	0.36	0.50
58.0	1.2	0.52	1.00	0.00	1.00	0.79	0.58	0.99	0.77	1.00	0.00	0.79	0.57	0.77
60.0	1.4	0.39	1.00	0.00	1.00	0.94	0.70	1.00	0.93	0.98	0.00	0.94	0.70	0.89
62.0	1.4	0.27	1.00	0.00	1.00	0.99	0.70	1.00	0.93	0.91	0.00	0.99	0.70	0.85
64.0	1.2	0.36	1.00	0.00	1.00	0.99	0.61	1.00	0.80	0.94	0.00	0.99	0.60	0.75
66.0	1.0	0.30	1.00	0.00	1.00	0.97	0.48	1.00	0.63	0.93	0.00	0.97	0.48	0.59
68.4	0.7	0.22	1.00	0.00	0.95	0.91	0.36	1.00	0.47	0.86	0.00	0.79	0.36	0.40
69.0	0.3	0.03	0.00	0.00	0.37	0.99	0.15	1.00	0.20	0.81	0.00	0.36	0.15	0.19
70.0	1.0	0.03	1.00	0.00	1.00	0.99	0.58	1.00	0.67	0.81	0.00	0.99	0.60	0.64
AVERAGE			0.91	0.04	0.87	0.81	0.46	0.84	0.60	0.96	0.04	0.61	0.38	0.59
10 cfs														
34.0	0.2	0.32	0.00	0.00	0.18	0.87	0.08	1.00	0.10	0.83	0.00	0.18	0.08	0.08
36.5	0.4	0.38	0.00	0.00	0.42	0.85	0.18	1.00	0.23	0.95	0.00	0.36	0.18	0.22
41.2	0.5	0.10	0.00	0.00	0.81	0.99	0.25	1.00	0.33	0.84	0.00	0.53	0.25	0.28
42.0	0.6	0.27	0.00	0.00	0.73	0.95	0.30	1.00	0.40	0.96	0.00	0.62	0.30	0.38
43.0	0.9	0.41	1.00	0.00	0.91	0.84	0.38	1.00	0.50	0.99	0.00	0.77	0.38	0.48
45.0	0.7	0.27	0.50	0.00	0.79	0.73	0.33	0.95	0.43	1.00	0.00	0.57	0.31	0.43
47.0	0.4	0.64	0.00	0.00	0.49	0.63	0.20	0.90	0.27	1.00	0.00	0.31	0.18	0.27
48.0	0.5	0.50	1.00	0.00	1.00	0.73	0.45	1.00	0.60	1.00	0.00	0.73	0.45	0.60
51.0	0.8	0.57	1.00	0.00	0.98	0.72	0.40	0.95	0.53	1.00	0.00	0.70	0.38	0.53
53.0	0.8	0.48	1.00	0.00	0.99	0.80	0.40	1.00	0.53	1.00	0.00	0.79	0.40	0.53
56.0	0.9	0.27	1.00	0.00	1.00	0.93	0.45	1.00	0.60	0.91	0.00	0.93	0.45	0.56
54.2	1.0	0.27	1.00	0.00	1.00	0.93	0.50	1.00	0.67	0.91	0.00	0.93	0.50	0.61
57.0	0.5	0.03	0.00	0.00	0.81	0.99	0.25	1.00	0.33	0.81	0.00	0.80	0.25	0.27
59.0	0.8	0.03	1.00	0.00	1.00	0.99	0.45	1.00	0.60	0.81	0.00	0.99	0.45	0.48
60.0	0.9	0.03	1.00	0.00	1.00	0.99	0.45	1.00	0.60	0.81	0.00	0.99	0.45	0.48
62.0	1.0	0.03	1.00	0.00	1.00	0.99	0.50	1.00	0.67	0.81	0.00	0.99	0.50	0.53
64.0	0.8	0.03	1.00	0.00	1.00	0.99	0.45	1.00	0.60	0.81	0.00	0.99	0.45	0.48
66.0	0.6	0.03	1.00	0.00	0.99	0.93	0.40	1.00	0.53	0.81	0.00	0.99	0.40	0.43
68.4	0.4	0.03	0.00	0.00	0.49	0.99	0.20	1.00	0.27	0.81	0.00	0.48	0.20	0.22
69.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.81	0.00	0.13	0.05	0.05
AVERAGE			0.58	0.00	0.79	0.89	0.34	0.99	0.45	0.90	0.00	0.69	0.33	0.40
5 cfs														
36.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.81	0.00	0.13	0.05	0.05
36.2	0.2	0.00	0.00	0.00	0.18	0.99	0.08	1.00	0.10	0.81	0.00	0.18	0.08	0.08
41.2	0.4	0.03	0.00	0.00	0.49	0.99	0.20	1.00	0.27	0.81	0.00	0.48	0.20	0.22
42.0	0.5	0.13	0.00	0.00	0.56	0.96	0.23	1.00	0.30	0.95	0.00	0.52	0.23	0.24
43.0	0.6	0.29	0.00	0.00	0.73	0.94	0.30	1.00	0.40	0.94	0.00	0.62	0.30	0.38
44.0	0.8	0.54	0.00	0.00	0.73	0.75	0.30	0.97	0.40	1.00	0.00	0.56	0.29	0.40
45.0	0.6	0.48	0.00	0.00	0.61	0.81	0.25	1.00	0.33	0.99	0.00	0.49	0.25	0.29
48.0	0.6	0.39	0.00	0.00	0.73	0.94	0.30	1.00	0.40	0.94	0.00	0.62	0.30	0.38
47.0	0.3	0.42	0.00	0.00	0.37	0.83	0.15	1.00	0.20	0.97	0.00	0.30	0.15	0.18
48.0	0.9	0.42	0.00	0.00	0.73	0.83	0.30	1.00	0.40	0.97	0.00	0.61	0.30	0.38
49.0	0.7	0.42	1.00	0.00	0.95	0.83	0.35	1.00	0.47	0.97	0.00	0.71	0.35	0.45
50.0	0.8	0.44	1.00	0.00	0.91	0.82	0.38	1.00	0.50	0.99	0.00	0.75	0.38	0.49
51.0	0.6	0.27	0.00	0.00	0.73	0.99	0.30	1.00	0.40	0.81	0.00	0.65	0.30	0.36
52.0	0.9	0.03	0.00	0.00	0.73	0.99	0.30	1.00	0.40	0.81	0.00	0.73	0.30	0.32
53.0	0.8	0.20	0.00	0.00	0.91	0.99	0.35	1.00	0.33	0.90	0.00	0.84	0.35	0.31
56.0	0.9	0.03	1.00	0.00	0.99	0.99	0.40	1.00	0.53	0.81	0.00	0.99	0.40	0.43
54.2	0.9	0.03	1.00	0.00	1.00	0.99	0.43	1.00	0.57	0.81	0.00	0.99	0.43	0.46
57.0	0.5	0.03	0.00	0.00	0.81	0.99	0.25	1.00	0.33	0.81	0.00	0.80	0.25	0.27
58.0	0.8	0.03	1.00	0.00	1.00	0.99	0.43	1.00	0.57	0.81	0.00	0.99	0.43	0.46
60.0	0.9	0.03	1.00	0.00	1.00	0.99	0.45	1.00	0.60	0.81	0.00	0.99	0.45	0.48
62.0	1.0	0.03	1.00	0.00	1.00	0.99	0.48	1.00	0.63	0.81	0.00	0.99	0.48	0.51
64.0	0.8	0.03	1.00	0.00	0.99	0.99	0.40	1.00	0.53	0.81	0.00	0.99	0.40	0.43
66.0	0.5	0.03	0.00	0.00	0.81	0.99	0.25	1.00	0.33	0.81	0.00	0.80	0.25	0.27
68.4	0.4	0.03	0.00	0.00	0.49	0.99	0.20	1.00	0.27	0.81	0.00	0.48	0.20	0.22
69.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.81	0.00	0.13	0.05	0.05
AVERAGE			0.22	0.00	0.67	0.93	0.29	1.00	0.27	0.87	0.00	0.62	0.29	0.33

J-728 Alameda Creek

Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 2
TRANS 2

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
30 cfs														
30.9	0.2	0.03	0.00	0.00	0.04	0.00	0.10	1.00	0.13	0.91	0.00	0.04	0.10	0.11
34.0	0.3	0.17	0.00	0.00	0.01	0.00	0.26	1.00	0.30	0.87	0.00	0.01	0.26	0.29
36.0	0.3	1.00	0.00	0.00	0.01	0.07	0.35	0.38	0.33	1.00	0.00	0.04	0.10	0.33
37.0	0.3	0.00	0.00	0.00	0.04	0.00	0.10	0.00	0.13	1.00	0.00	0.00	0.00	0.13
39.0	0.3	0.00	0.00	0.00	0.37	0.34	0.15	0.71	0.20	1.00	0.00	0.12	0.11	0.20
20.0	0.4	1.04	0.00	1.00	0.48	0.00	0.20	0.21	0.27	0.29	0.00	0.00	0.04	0.27
30.0	0.5	1.04	0.00	1.00	0.01	0.00	0.25	0.15	0.33	1.00	0.00	0.00	0.04	0.32
30.0	0.5	0.04	0.00	0.00	0.00	0.00	0.20	0.21	0.27	1.00	0.00	0.00	0.04	0.27
28.0	0.5	0.03	0.00	0.00	0.07	0.00	0.13	1.00	0.20	0.91	0.00	0.00	0.13	0.19
26.0	0.5	1.00	0.00	0.00	0.00	0.00	0.20	0.25	0.27	1.00	0.00	0.00	0.00	0.27
26.0	0.5	0.27	0.00	0.00	0.00	0.73	0.13	0.96	0.17	1.00	0.00	0.00	0.13	0.17
24.0	0.4	0.01	0.00	0.00	0.00	0.42	0.20	0.77	0.27	1.00	0.00	0.21	0.15	0.27
41.0	0.0	1.44	0.00	0.79	0.01	0.00	0.25	0.29	0.33	1.00	0.00	0.00	0.07	0.33
42.0	0.8	1.04	0.00	1.00	0.07	0.00	0.28	0.21	0.27	1.00	0.00	0.00	0.06	0.27
44.0	0.4	0.73	0.00	0.00	0.00	0.52	0.20	0.82	0.27	1.00	0.00	0.26	0.16	0.27
46.0	0.5	1.07	0.00	0.96	0.01	0.00	0.25	0.23	0.33	1.00	0.00	0.00	0.08	0.33
47.0	0.9	1.08	0.00	1.00	0.73	0.00	0.30	0.11	0.40	1.00	0.00	0.00	0.03	0.40
48.0	0.9	1.79	1.00	1.00	0.98	0.00	0.10	0.13	0.53	1.00	1.00	0.00	0.07	0.53
50.0	0.7	2.07	1.00	1.00	0.98	0.00	0.39	0.00	0.47	0.00	1.00	0.00	0.00	0.00
51.0	0.7	2.02	1.00	0.98	0.95	0.00	0.38	0.00	0.47	0.00	0.98	0.00	0.00	0.00
52.0	0.8	2.01	1.00	0.98	1.00	0.00	0.38	0.00	0.50	0.00	0.98	0.00	0.00	0.00
54.0	0.9	2.08	0.00	1.00	0.73	0.00	0.28	0.09	0.40	0.84	0.00	0.00	0.00	0.34
56.0	0.9	1.79	0.00	1.00	0.73	0.00	0.30	0.15	0.40	1.00	0.00	0.00	0.05	0.40
54.0	0.3	0.15	0.00	1.00	0.27	0.00	0.15	0.99	0.20	0.95	0.00	0.00	0.01	0.13
58.0	0.9	0.96	0.00	0.58	0.07	0.25	0.29	0.44	0.27	1.00	0.00	0.17	0.13	0.27
60.2	0.4	1.22	0.00	0.48	0.18	0.11	0.20	0.46	0.27	1.00	0.00	0.06	0.09	0.27
61.0	0.6	1.20	0.00	0.43	0.07	0.13	0.28	0.47	0.27	1.00	0.00	0.12	0.08	0.27
62.5	0.3	1.10	0.00	0.36	0.27	0.14	0.15	0.61	0.20	1.00	0.00	0.05	0.09	0.20
64.0	0.3	1.63	0.00	0.00	0.01	0.29	0.25	0.69	0.33	1.00	0.00	0.17	0.17	0.33
67.0	0.3	1.86	0.00	0.00	0.04	0.37	0.10	0.73	0.13	1.00	0.00	0.09	0.07	0.13
70.0	0.2	0.54	0.00	0.00	0.27	0.69	0.10	0.93	0.20	1.00	0.00	0.25	0.14	0.20
73.0	0.2	0.54	0.00	0.00	0.27	0.69	0.13	0.93	0.17	1.00	0.00	0.25	0.17	0.17
73.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.05
AVERAGE			0.13	0.48	0.54	0.26	0.22	0.48	0.29	0.87	0.11	0.10	0.08	0.24
10 cfs														
22.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
24.0	0.3	0.23	0.00	0.00	0.20	0.91	0.13	1.00	0.17	0.99	0.00	0.18	0.13	0.15
26.0	0.3	0.59	0.00	0.00	0.20	0.69	0.13	0.83	0.17	1.00	0.00	0.21	0.13	0.17
27.5	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
29.0	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.18	0.08	0.09
30.5	0.3	0.79	0.00	0.00	0.24	0.49	0.10	0.90	0.13	1.00	0.00	0.12	0.09	0.13
32.0	0.3	0.79	0.00	0.00	0.24	0.49	0.13	0.90	0.17	1.00	0.00	0.12	0.12	0.17
33.0	0.2	0.92	0.00	0.00	0.24	0.29	0.10	0.88	0.13	1.00	0.00	0.07	0.07	0.13
35.0	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.18	0.08	0.09
36.0	0.3	0.27	0.00	0.00	0.20	0.95	0.13	1.00	0.17	0.95	0.00	0.20	0.13	0.16
38.0	0.2	0.29	0.00	0.00	0.20	0.90	0.10	1.00	0.13	0.91	0.00	0.20	0.10	0.13
39.5	0.2	0.44	0.00	0.00	0.20	0.82	0.13	1.00	0.17	0.98	0.00	0.25	0.13	0.19
41.0	0.3	1.32	0.00	0.00	0.27	0.57	0.15	0.39	0.20	1.00	0.00	0.22	0.13	0.20
42.5	0.3	1.01	0.00	0.00	0.27	0.20	0.13	0.62	0.20	1.00	0.00	0.07	0.08	0.20
44.0	0.0	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
45.5	0.3	1.32	0.00	0.00	0.27	0.07	0.15	0.39	0.20	1.00	0.00	0.02	0.06	0.20
47.0	0.4	1.79	0.00	1.00	0.48	0.00	0.20	0.17	0.27	1.00	0.00	0.00	0.03	0.27
48.0	0.5	1.62	0.00	1.00	0.97	0.00	0.28	0.22	0.37	1.00	0.00	0.00	0.06	0.37
50.0	0.5	0.15	0.00	1.00	0.66	0.00	0.23	0.07	0.30	0.88	0.00	0.00	0.01	0.26
51.0	0.5	1.26	0.00	0.22	0.61	0.18	0.25	0.54	0.33	1.00	0.00	0.11	0.15	0.33
52.2	0.5	2.07	0.00	1.00	0.98	0.00	0.35	0.00	0.33	0.00	0.00	0.00	0.00	0.00
54.2	0.4	1.74	0.00	1.00	0.48	0.00	0.20	0.18	0.27	1.00	0.00	0.00	0.04	0.27
55.5	0.2	1.58	0.00	0.99	0.27	0.00	0.15	0.22	0.20	1.00	0.00	0.00	0.03	0.20
54.8	0.2	0.91	0.00	0.00	0.24	0.42	0.10	0.77	0.13	1.00	0.00	0.10	0.08	0.13
54.3	0.4	0.79	0.00	0.00	0.43	1.00	0.18	0.79	0.23	1.00	0.00	0.20	0.14	0.23
60.2	0.0	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
61.0	0.4	0.54	0.00	0.00	0.48	0.75	0.20	0.97	0.27	1.00	0.00	0.27	0.19	0.27
62.2	0.2	0.81	0.00	0.00	0.24	0.56	0.10	0.91	0.13	1.00	0.00	0.13	0.09	0.13
63.3	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.19	0.09	0.09
63.8	0.0	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
65.0	0.2	0.81	0.00	0.00	0.20	0.56	0.13	0.91	0.17	1.00	0.00	0.20	0.11	0.17
67.0	0.0	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
73.0	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.19	0.09	0.09
73.9	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
AVERAGE			0.06	0.22	0.29	0.58	0.13	0.75	0.19	0.98	0.00	0.11	0.07	0.14
3 cfs														
24.9	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.19	0.09	0.09
26.9	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.19	0.09	0.09
27.5	0.1	0.03	0.00	0.00	0.06	0.99	0.03	1.00	0.03	0.91	0.00	0.06	0.03	0.03
29.0	0.1	0.03	0.00	0.00	0.06	0.99	0.03	1.00	0.03	0.91	0.00	0.06	0.03	0.03
30.3	0.1	0.03	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
32.0	0.1	0.03	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
33.5	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.19	0.09	0.09
35.0	0.1	0.03	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
36.5	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.19	0.09	0.09
38.0	0.1	0.03	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
39.5	0.2	0.03	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.19	0.09	0.09
41.0	0.2	0.82	0.00	0.00	0.24	0.40	0.10	0.75	0.13	1.00	0.00	0.10	0.07	0.13
42.5	0.2	0.00	0.00	0.00	0.24	0.13	0.10	0.47	0.13	1.00	0.00	0.03	0.04	0.13
43.5	0.2	0.69	0.00	0.00	0.24	0.58	0.10	0.94	0.13	1.00	0.00	0.14	0.09	0.13
44.9	0.1	0.03	0.00	0.00	0.06	0.99	0.03	1.00	0.03	0.91	0.00	0.06	0.03	0.03
45.5	0.3	1.44	0.00	0.79	0.30	0.00	0.15	0.29	0.17	1.00	0.00	0.01	0.04	0.17
47.0	0.3	1.97	0.00	0.00	0.27	0.00	0.15	0.23	0.20	1.00	0.00	0.00	0.03	0.20
48.8	0.5	1.20	0.00	0.48	0.56	0.11	0.23	0.46	0.30	1.00	0.00	0.06	0.10	0.30
50.0	0.3	1.26	0.00	0.50	0.37	0.10	0.18	0.44	0.20	1.00	0.00	0.07	0.07	0.20
51.5	0.4	1.25	0.00	0.50	0.48	0.10	0.20	0.44	0.27	1.00	0.00	0.07	0.08	0.27
52.2	0.5	2.23	0.00	1.00	0.55	0.00	0.23	0.06	0.30	0.00	0.00	0.00	0.01	0.19
54.0	0.4	1.32	0.00	0.60	0.42	0.07	0.18	0.28	0.23	1.00	0.00	0.04	0.07	0.23
55.0	0.3	1.01	0.00	0.15	0.27	0.20	0.15	0.62	0.20	1.00	0.00	0.07	0.08	0.20
56.9	0.2	1.27	0.00	0.97	0.24	0.06	0.10	0.36	0.13	1.00	0.00	0.01	0.03	0.13
58.9	0.2	0.16	0.00	0.00	0.24	0.94	0.10	1.00	0.13	0.98	0.00	0.23	0.10	0.12
60.2	0.0		0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
61.5	0.2	0.00	0.00	0.00	0.20	0.56	0.13	0.97	0.17	1.00	0.00	0.19	0.11	0.17
62.3	0.1	0.00	0.00	0.00	0.06	0.99	0.03	1.00	0.03	0.91	0.00	0.06	0.03	0.03
63.2	0.1	0.03	0.00	0.00	0.06	0.99	0.03	1.00	0.03	0.91	0.00	0.06	0.03	0.03
63.9	0.1	0.03	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
65.5	0.2	0.31	0.00	0.00	0.24	0.99	0.10	1.00	0.13	0.92	0.00	0.21	0.10	0.13
AVERAGE			0.00	0.20	0.23	0.62	0.09	0.77	0.13	0.99	0.00	0.09	0.06	0.11

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 2
TRANS 3

			HABITAT SUITABILITY								COMBINED DEPTH AND VELOCITY			
	DEPTH	VELOCITY	SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
20 cfs														
0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.91	0.00	0.00	0.00	0.00
7.2	0.1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.91	0.00	0.00	0.00	0.00
8.0	0.8	0.00	0.00	0.00	0.79	0.00	0.00	1.00	0.40	0.91	0.00	0.79	0.00	0.00
9.0	0.5	0.00	0.00	0.00	0.91	0.00	0.26	1.00	0.00	0.91	0.00	0.91	0.00	0.00
10.4	0.3	0.00	0.40	0.00	0.79	0.00	0.32	1.00	0.42	0.91	0.00	0.77	0.00	0.00
11.6	0.2	0.00	1.00	0.00	1.00	0.00	1.00	1.00	0.95	0.91	0.00	1.00	0.00	0.00
12.5	1.0	0.61	1.00	0.00	1.00	0.00	0.95	0.91	0.97	1.00	0.00	1.00	0.00	0.00
13.0	1.0	0.81	1.00	0.00	1.00	0.00	0.90	0.81	0.97	1.00	0.00	1.00	0.00	0.00
14.0	1.4	1.49	1.00	0.00	1.00	0.00	0.75	0.25	0.89	1.00	0.00	1.00	0.00	0.00
15.0	1.7	1.91	1.00	0.00	0.96	0.00	0.66	0.13	1.00	1.00	0.00	0.96	0.00	0.00
16.0	1.1	2.75	1.00	0.00	1.00	0.00	0.53	0.00	0.73	0.00	0.00	0.00	0.00	0.00
17.0	1.9	3.27	1.00	0.00	1.00	0.00	0.90	0.00	1.00	0.25	0.00	0.00	0.00	0.25
18.0	1.8	1.48	1.00	0.00	1.00	0.00	0.90	0.25	1.00	1.00	0.00	0.00	0.00	1.00
19.0	1.4	0.89	1.00	0.00	1.00	0.00	0.75	0.89	0.93	1.00	0.00	0.00	0.67	0.93
20.0	1.3	2.01	1.00	0.00	1.00	0.00	0.90	0.10	0.97	0.99	1.00	0.00	0.00	0.99
21.0	1.3	1.73	1.00	0.00	1.00	0.00	0.90	0.17	0.95	1.00	1.00	0.00	0.00	0.95
22.0	1.2	1.26	1.00	0.04	1.00	0.00	0.80	0.84	0.77	1.00	0.04	0.00	0.21	0.77
23.0	1.1	1.20	1.00	0.00	1.00	0.13	0.63	0.97	0.75	1.00	0.00	0.13	0.28	0.75
24.0	0.9	0.78	1.00	0.00	1.00	0.49	0.45	0.96	0.59	1.00	0.00	0.49	0.34	0.59
25.0	1.0	0.90	1.00	0.00	1.00	0.40	0.50	0.75	0.67	1.00	0.00	0.40	0.37	0.67
26.0	0.8	0.64	1.00	0.00	0.98	0.00	0.40	0.50	0.53	1.00	0.00	0.00	0.20	0.53
27.0	0.6	0.47	0.00	0.00	0.73	0.21	0.20	1.00	0.40	0.98	0.00	0.00	0.00	0.39
28.0	0.4	0.03	0.00	0.00	0.46	0.98	0.20	1.00	0.27	0.91	0.00	0.46	0.00	0.25
29.0	0.2	0.03	0.00	0.00	0.27	0.98	0.16	1.00	0.20	0.91	0.00	0.26	0.15	0.18
30.0	0.2	0.03	0.00	0.00	0.24	0.98	0.13	1.00	0.13	0.91	0.00	0.24	0.13	0.11
AVERAGE			0.68	0.21	0.80	0.54	0.46	0.68	0.53	0.96	0.21	0.34	0.24	0.51
10 cfs														
0.0	0.3	0.00	0.00	0.00	0.27	0.00	0.16	1.00	0.20	0.91	0.00	0.00	0.15	0.19
9.0	0.0		0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
10.4	0.3	0.22	0.00	0.00	0.24	0.98	0.13	1.00	0.13	0.91	0.00	0.24	0.13	0.11
11.6	0.4	0.38	0.00	0.00	0.19	0.87	0.06	1.00	0.10	0.82	0.00	0.19	0.06	0.08
12.5	0.8	0.21	1.00	0.00	1.00	0.98	0.46	1.00	0.26	1.00	0.00	0.98	0.46	0.26
13.0	0.8	0.16	1.00	0.00	0.91	0.84	0.38	1.00	0.50	0.98	0.00	0.98	0.38	0.42
14.0	1.2	0.74	1.00	0.00	1.00	0.52	0.69	0.82	0.90	1.00	0.00	0.52	0.49	0.90
15.0	1.3	0.67	1.00	0.00	1.00	0.79	0.90	0.86	0.97	1.00	0.00	0.79	0.82	0.97
16.0	0.9	1.40	1.00	0.71	1.00	0.04	0.46	0.33	0.96	1.00	0.71	0.04	0.15	0.90
17.0	1.0	1.22	1.00	0.48	1.00	0.11	0.55	0.46	0.97	1.00	0.48	0.11	0.26	0.97
18.0	1.4	0.42	1.00	0.00	1.00	0.63	0.70	1.00	0.93	0.97	0.00	0.63	0.70	0.90
19.0	1.2	0.24	1.00	0.00	1.00	0.90	0.80	1.00	0.85	0.90	0.00	0.90	0.80	0.73
20.0	1.2	0.30	1.00	0.00	1.00	0.78	0.58	0.98	0.77	1.00	0.00	0.78	0.28	0.77
21.0	1.0	1.19	1.00	0.41	1.00	0.12	0.46	0.49	0.93	1.00	0.41	0.12	0.23	0.93
22.0	0.9	0.71	1.00	0.00	1.00	0.53	0.48	0.94	0.85	1.00	0.00	0.53	0.39	0.85
23.0	0.7	0.64	1.00	0.00	0.96	0.63	0.36	0.90	0.47	1.00	0.00	0.54	0.31	0.47
24.0	0.7	0.44	0.50	0.00	0.73	0.92	0.33	1.00	0.43	0.98	0.00	0.66	0.33	0.42
25.0	0.7	0.43	1.00	0.00	0.88	0.93	0.36	1.00	0.47	0.97	0.00	0.71	0.35	0.47
26.0	0.6	0.57	0.00	0.00	0.81	0.86	0.26	1.00	0.33	0.96	0.00	0.00	0.25	0.32
27.0	0.4	0.21	0.00	0.00	0.46	0.98	0.20	1.00	0.27	0.92	0.00	0.45	0.20	0.26
28.0	0.2	0.03	0.00	0.00	0.16	0.98	0.09	1.00	0.13	0.91	0.00	0.16	0.09	0.09
29.0	0.1	0.03	0.00	0.00	0.13	0.98	0.06	1.00	0.07	0.91	0.00	0.13	0.06	0.06
AVERAGE			0.61	0.07	0.71	0.72	0.39	0.89	0.48	0.92	0.07	0.44	0.30	0.46
5 cfs														
0.0	0.3	0.00	0.00	0.00	0.30	0.98	0.13	1.00	0.17	0.91	0.00	0.30	0.13	0.14
9.0	0.2	0.00	0.00	0.00	0.13	0.98	0.06	1.00	0.07	0.91	0.00	0.13	0.06	0.06
10.4	0.2	0.00	0.00	0.00	0.24	0.98	0.10	1.00	0.13	0.91	0.00	0.24	0.10	0.11
11.6	0.1	0.00	0.00	0.00	0.09	0.98	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
12.5	0.7	0.00	0.00	0.00	0.73	0.98	0.33	1.00	0.43	0.91	0.00	0.98	0.33	0.36
13.0	1.0	0.36	1.00	0.00	1.00	0.97	0.92	1.00	0.97	0.93	0.00	0.97	0.92	0.93
14.0	1.1	0.54	1.00	0.00	1.00	0.75	0.94	0.97	0.73	1.00	0.00	0.75	0.92	0.73
15.0	1.3	0.62	1.00	0.00	1.00	0.77	0.65	0.98	0.97	1.00	0.00	0.77	0.64	0.97
16.0	0.7	0.79	1.00	0.00	0.26	0.46	0.26	0.79	0.47	1.00	0.00	0.00	0.26	0.47
17.0	1.4	0.62	1.00	0.00	1.00	0.65	0.70	0.91	0.90	1.00	0.00	0.65	0.63	0.90
18.0	1.3	0.03	1.00	0.00	1.00	0.29	0.43	1.00	0.80	0.91	0.00	0.32	0.38	0.80
19.0	1.1	0.08	1.00	0.00	1.00	0.57	0.54	1.00	0.73	0.92	0.00	0.57	0.54	0.67
20.0	0.8	0.36	1.00	0.00	0.81	0.98	0.38	1.00	0.52	0.94	0.00	0.79	0.38	0.47
21.0	0.8	0.88	1.00	0.00	0.98	0.34	0.40	0.71	0.53	1.00	0.00	0.32	0.28	0.52
22.0	0.8	0.48	1.00	0.00	0.98	0.82	0.46	1.00	0.53	1.00	0.00	0.79	0.46	0.52
23.0	0.5	0.48	0.00	0.00	0.61	0.90	0.35	1.00	0.33	1.00	0.00	0.48	0.35	0.33
24.0	0.9	0.15	0.00	0.00	0.73	0.63	0.30	1.00	0.40	0.97	0.00	0.00	0.30	0.39
25.0	0.6	0.13	0.00	0.00	0.73	0.98	0.30	1.00	0.40	0.98	0.00	0.00	0.30	0.39
26.0	0.4	0.08	0.00	0.00	0.46	0.97	0.20	1.00	0.27	0.92	0.00	0.00	0.20	0.25
27.0	0.2	0.15	0.00	0.00	0.24	0.98	0.10	1.00	0.13	0.94	0.00	0.00	0.10	0.11
28.0	0.2	0.03	0.00	0.00	0.24	0.98	0.10	1.00	0.13	0.91	0.00	0.24	0.10	0.11
29.0	0.1	0.03	0.00	0.00	0.09	0.98	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
AVERAGE			0.48	0.00	0.66	0.67	0.32	0.97	0.42	0.96	0.00	0.53	0.31	0.39

Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 2
TRANS 4

DIST	DEPTH (ft)	VELOCITY (fps)	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
			Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
35 cfs														
0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVERAGE			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70 cfs														
0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVERAGE			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
105 cfs														
0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVERAGE			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J-728 Alamoda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 2
TRANS 5

			HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
	DEPTH	VELOCITY												
REACH	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
20 cfs														
	0.5	0.81	0.50	0.00	0.50	0.98	0.03	0.97	0.30	1.00	0.00	0.49	0.27	0.30
	0.5	1.22	0.00	0.10	0.81	0.19	0.05	0.90	0.30	1.00	0.00	0.11	0.15	0.20
	0.5	1.91	0.00	1.00	0.70	0.00	0.20	0.13	0.45	1.00	0.00	0.00	0.04	0.40
	0.4	0.74	0.00	0.00	0.42	0.52	0.10	0.82	0.23	1.00	0.00	0.22	0.10	0.23
	0.6	1.62	1.00	0.00	1.00	0.00	0.45	0.24	0.00	1.00	0.00	0.00	0.11	0.00
	0.2	1.15	0.00	0.00	0.24	0.14	0.15	0.51	0.13	1.00	0.00	0.03	0.04	0.03
	0.7	0.00	1.00	0.00	0.96	0.00	0.26	1.00	0.47	0.81	0.00	0.84	0.26	0.38
	0.8	1.36	0.00	0.00	0.79	0.00	0.20	1.00	0.45	0.94	0.00	0.63	0.20	0.42
	0.7	0.00	1.00	0.00	0.96	0.00	0.26	1.00	0.47	0.81	0.00	0.84	0.26	0.38
	0.7	0.00	1.00	0.00	0.96	0.07	0.26	1.00	0.47	0.82	0.00	0.89	0.26	0.39
	0.9	0.53	1.00	0.00	1.00	0.00	0.45	1.00	0.00	0.81	0.00	0.00	0.45	0.00
	0.4	1.00	0.00	0.10	0.46	0.18	0.05	0.80	0.27	1.00	0.00	0.08	0.13	0.27
	1.0	0.40	1.00	0.00	1.00	0.00	0.50	1.00	0.57	0.97	0.00	0.00	0.50	0.55
	0.5	1.44	0.00	0.70	0.81	0.00	0.25	0.20	0.23	1.00	0.00	0.00	0.20	0.23
	1.0	0.49	1.00	0.00	1.00	0.00	0.50	1.00	0.00	1.00	0.00	0.00	0.50	0.00
	1.2	0.00	1.00	0.00	1.00	0.10	0.60	1.00	0.00	1.00	0.00	0.10	0.54	0.00
	1.3	1.19	0.00	0.39	1.00	0.13	0.65	0.40	0.00	1.00	0.00	0.13	0.26	0.00
	1.4	1.28	0.00	0.44	1.00	0.00	0.70	0.39	0.00	1.00	0.00	0.00	0.26	0.00
	0.6	1.27	0.00	0.67	0.81	0.00	0.25	0.20	0.23	1.00	0.00	0.00	0.20	0.23
	0.4	1.10	0.00	0.29	0.42	0.16	0.10	0.55	0.23	1.00	0.00	0.07	0.10	0.23
	1.3	0.00	1.00	0.00	1.00	0.22	0.65	0.94	0.97	1.00	0.13	0.22	0.62	0.97
	1.2	0.53	1.00	0.00	1.00	0.79	0.60	0.88	0.00	1.00	0.00	0.79	0.53	0.00
	1.3	0.50	1.00	0.00	1.00	0.89	0.65	1.00	0.57	0.81	0.00	0.89	0.65	0.75
	0.8	0.00	0.00	0.00	0.67	0.99	0.26	1.00	0.27	0.81	0.00	0.99	0.26	0.26
AVERAGE			0.54	0.24	0.78	0.40	0.39	0.71	0.32	0.95	0.10	0.40	0.38	0.40
10 cfs														
	0.1	0.52	0.00	0.00	0.12	0.00	0.05	1.00	0.07	0.91	0.00	0.12	0.05	0.05
	0.2	0.03	0.00	0.00	0.19	0.00	0.09	1.00	0.10	0.91	0.00	0.19	0.09	0.09
	0.4	0.81	0.00	0.01	0.48	0.21	0.20	0.59	0.27	1.00	0.00	0.10	0.14	0.27
	0.4	0.74	0.00	0.00	0.48	0.53	0.20	0.82	0.27	1.00	0.00	0.26	0.16	0.27
	0.5	0.66	0.00	0.00	0.42	0.84	0.23	0.98	0.26	1.00	0.00	0.35	0.19	0.26
	0.4	1.13	0.00	0.20	0.48	0.15	0.20	0.53	0.27	1.00	0.00	0.07	0.11	0.27
	0.5	0.10	0.00	0.00	0.81	0.00	0.25	1.00	0.23	0.94	0.00	0.00	0.25	0.23
	0.4	0.00	0.00	0.00	0.70	0.00	0.20	1.00	0.45	0.81	0.00	0.70	0.20	0.32
	0.4	0.38	0.00	0.00	0.42	0.94	0.19	1.00	0.23	0.94	0.00	0.79	0.19	0.22
	0.6	0.15	0.00	0.00	0.70	0.00	0.30	1.00	0.40	0.94	0.00	0.70	0.30	0.34
	0.1	0.00	0.00	0.00	0.15	0.00	0.05	1.00	0.08	0.91	0.00	0.15	0.05	0.06
	0.3	0.28	1.00	0.00	1.00	0.00	0.45	1.00	0.48	0.91	0.00	0.00	0.45	0.00
	0.3	0.52	0.00	0.00	0.24	0.77	0.10	0.98	0.13	1.00	0.00	0.18	0.10	0.13
	0.3	0.33	1.00	0.00	0.96	0.67	0.45	1.00	0.53	0.80	0.00	0.65	0.45	0.50
	0.7	0.28	1.00	0.00	0.96	0.94	0.26	1.00	0.47	0.98	0.00	0.79	0.26	0.45
	0.9	1.10	1.00	0.29	1.00	0.15	0.43	0.55	0.67	1.00	0.29	0.15	0.23	0.67
	1.1	0.00	1.00	0.00	1.00	0.11	0.48	1.00	0.00	1.00	0.00	0.11	0.00	0.00
	0.3	0.03	0.00	0.00	0.19	0.96	0.09	1.00	0.10	0.91	0.00	0.19	0.09	0.09
	0.1	0.00	0.00	0.00	0.12	0.98	0.05	1.00	0.07	0.91	0.00	0.12	0.05	0.06
	1.1	1.26	1.00	0.54	1.00	0.00	0.53	0.38	0.79	1.00	0.00	0.00	0.38	0.79
	0.9	1.18	1.00	0.38	1.00	0.13	0.43	0.48	0.67	1.00	0.38	0.13	0.21	0.67
	0.8	0.54	1.00	0.00	1.00	0.75	0.40	0.87	0.00	1.00	0.00	0.75	0.40	0.00
	0.3	0.25	0.00	0.00	0.36	0.90	0.13	1.00	0.17	0.90	0.00	0.27	0.13	0.15
AVERAGE			0.28	0.09	0.52	0.66	0.26	0.89	0.34	0.92	0.08	0.35	0.20	0.29
5 cfs														
	0.1	0.03	0.00	0.00	0.06	0.99	0.03	1.00	0.03	0.81	0.00	0.06	0.03	0.03
	0.2	0.00	0.00	0.00	0.19	0.89	0.08	1.00	0.10	0.91	0.00	0.19	0.08	0.09
	0.2	0.00	0.00	0.00	0.24	0.81	0.10	1.00	0.13	0.98	0.00	0.24	0.10	0.13
	0.4	0.71	0.00	0.00	0.48	0.50	0.20	0.94	0.27	1.00	0.00	0.27	0.17	0.27
	0.2	0.40	0.00	0.01	0.24	0.31	0.10	0.59	0.13	1.00	0.00	0.08	0.07	0.13
	0.4	0.03	0.00	0.00	0.42	0.28	0.18	1.00	0.23	0.81	0.00	0.12	0.18	0.19
	0.4	0.00	0.00	0.00	0.48	0.38	0.20	1.00	0.27	0.91	0.00	0.18	0.20	0.25
	0.3	0.07	0.00	0.00	0.36	0.72	0.13	0.86	0.17	1.00	0.00	0.22	0.13	0.17
	0.4	0.00	0.00	0.00	0.48	0.94	0.20	1.00	0.27	0.81	0.00	0.48	0.20	0.22
	0.6	0.20	0.00	0.00	0.70	0.00	0.30	1.00	0.40	0.98	0.00	0.67	0.30	0.35
	0.1	0.00	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.12	0.05	0.06
	0.9	0.27	1.00	0.00	0.91	0.85	0.38	1.00	0.50	0.96	0.00	0.78	0.38	0.47
	0.3	0.46	0.00	0.00	0.27	0.96	0.13	0.98	0.20	1.00	0.00	0.27	0.13	0.20
	0.8	0.59	0.00	0.00	0.67	0.69	0.26	0.82	0.27	1.00	0.00	0.46	0.26	0.27
	0.7	0.71	0.00	0.00	0.60	0.72	0.23	0.94	0.43	1.00	0.00	0.43	0.23	0.43
	0.1	0.03	0.00	0.00	0.06	0.99	0.03	1.00	0.03	0.91	0.00	0.06	0.03	0.03
	0.1	0.03	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.12	0.05	0.06
	1.0	0.91	1.00	0.00	1.00	0.43	0.48	0.77	0.63	1.00	0.00	0.43	0.38	0.63
	0.7	0.91	1.00	0.13	0.79	0.20	0.33	0.82	0.43	1.00	0.07	0.16	0.20	0.43
	0.7	0.37	1.00	0.00	0.96	0.79	0.26	1.00	0.47	0.98	0.00	0.82	0.26	0.47
	0.9	0.00	0.00	0.00	0.73	1.00	0.30	1.00	0.40	0.91	0.00	0.73	0.30	0.36
	0.4	0.00	1.00	0.00	0.24	0.99	1.00	1.00	0.13	0.91	0.00	0.24	1.00	0.91
	0.8	0.00	0.00	0.00	0.67	0.99	0.26	1.00	0.27	0.91	0.00	0.99	0.26	0.25
AVERAGE			0.22	0.21	0.47	0.73	0.24	0.90	0.30	0.96	0.02	0.34	0.23	0.28

J-729 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 2
TRANS 0

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV.	ADULT
30 cfs														
94.9	0.1	0.00	0.00	0.99	0.04	0.99	0.00	1.00	0.00	0.91	0.00	0.04	0.00	0.00
94.8	0.1	0.02	0.00	0.99	0.10	0.99	0.07	1.00	0.00	0.91	0.00	0.10	0.07	0.07
90.0	0.2	0.00	0.00	0.99	0.04	0.99	0.10	1.00	0.13	0.91	0.00	0.04	0.10	0.11
94.9	0.1	0.02	0.00	0.99	0.10	0.99	0.00	1.00	0.00	0.91	0.00	0.10	0.00	0.00
87.0	0.3	0.00	0.00	0.00	0.20	0.99	0.13	1.00	0.17	0.91	0.00	0.20	0.13	0.14
79.0	0.1	0.00	0.00	0.00	0.10	0.99	0.00	1.00	0.00	0.91	0.00	0.10	0.00	0.00
88.0	0.2	0.00	0.00	0.00	0.20	0.99	0.10	1.00	0.13	0.91	0.00	0.20	0.10	0.11
89.1	0.3	0.00	0.00	0.00	0.29	0.99	0.52	0.93	0.43	1.00	0.00	0.29	0.52	0.43
89.7	0.7	0.04	1.00	0.00	0.00	0.34	0.26	0.71	0.47	1.00	0.00	0.29	0.26	0.47
87.3	0.6	0.06	1.00	0.00	0.00	0.07	0.40	0.38	0.63	1.00	0.00	0.07	0.15	0.63
91.4	0.3	1.50	1.00	0.00	1.00	0.00	0.40	0.22	0.90	0.00	0.00	0.00	0.10	0.00
89.1	0.3	1.51	1.00	0.00	1.00	0.00	0.40	0.22	0.90	0.00	0.00	0.00	0.10	0.00
90.0	0.6	1.54	1.00	0.00	0.94	0.00	0.40	0.15	0.63	1.00	0.00	0.00	0.06	0.63
90.3	0.6	1.54	1.00	0.00	0.94	0.00	0.40	0.15	0.63	1.00	0.00	0.00	0.06	0.63
90.5	0.7	2.01	1.00	0.00	0.88	0.00	0.20	0.10	0.47	0.00	0.00	0.00	0.00	0.00
90.0	0.8	2.05	1.00	0.00	0.82	0.00	0.40	0.08	0.63	0.00	0.00	0.00	0.00	0.00
87.1	0.9	2.52	1.00	0.00	0.70	0.00	0.40	0.06	0.67	0.00	0.00	0.00	0.00	0.00
87.9	0.9	2.52	1.00	0.00	1.00	0.00	0.40	0.06	0.67	0.00	0.00	0.00	0.00	0.00
88.2	0.9	2.54	1.00	0.00	1.00	0.00	0.40	0.06	0.67	0.00	0.00	0.00	0.00	0.00
88.3	0.9	2.71	1.00	0.00	0.98	0.00	0.40	0.03	0.63	0.00	0.00	0.00	0.00	0.00
100.0	0.9	2.90	1.00	0.00	0.94	0.00	0.40	0.03	0.63	0.00	0.00	0.00	0.00	0.00
101.1	0.9	2.94	1.00	0.00	0.94	0.00	0.40	0.04	0.63	0.00	0.00	0.00	0.00	0.00
101.3	0.9	2.97	1.00	0.00	0.94	0.00	0.40	0.05	0.63	0.00	0.00	0.00	0.00	0.00
100.3	0.9	3.00	1.00	0.00	0.91	0.00	0.20	0.05	0.60	0.00	0.00	0.00	0.00	0.00
100.9	0.9	3.00	1.00	0.00	0.91	0.00	0.20	0.05	0.60	0.00	0.00	0.00	0.00	0.00
104.1	0.5	3.30	0.00	1.00	0.91	0.00	0.20	0.04	0.30	0.00	0.00	0.00	0.00	0.00
104.3	0.9	3.31	0.00	1.00	0.91	0.00	0.20	0.03	0.37	0.00	0.00	0.00	0.00	0.00
106.3	0.5	1.71	0.00	1.00	0.91	0.00	0.20	0.10	0.30	1.00	0.00	0.00	0.00	0.00
106.3	0.5	2.10	0.00	1.00	0.91	0.00	0.20	0.06	0.30	0.70	0.00	0.00	0.00	0.00
107.2	0.5	1.15	0.00	0.39	0.91	0.11	0.20	0.51	0.30	1.00	0.00	0.00	0.10	0.00
107.3	0.5	1.15	0.00	0.39	0.91	0.11	0.20	0.51	0.30	1.00	0.00	0.00	0.10	0.00
108.3	0.5	1.27	0.00	0.53	0.91	0.09	0.20	0.40	0.30	1.00	0.00	0.00	0.08	0.00
109.1	0.5	1.40	0.00	0.67	0.91	0.07	0.20	0.25	0.30	1.00	0.00	0.00	0.05	0.00
110.5	0.4	0.99	0.00	0.13	0.94	0.20	0.20	0.64	0.27	1.00	0.00	0.11	0.13	0.07
111.3	0.5	0.99	0.00	0.13	0.91	0.20	0.20	0.64	0.30	1.00	0.00	0.10	0.13	0.07
113.9	0.5	0.72	0.00	0.26	0.91	0.47	0.20	1.00	0.30	0.80	0.00	0.20	0.20	0.21
113.8	0.5	0.62	0.00	0.16	0.91	0.69	0.20	1.00	0.30	0.60	0.00	0.10	0.20	0.27
114.8	0.5	0.62	0.00	0.16	0.91	0.69	0.20	1.00	0.30	0.60	0.00	0.10	0.20	0.27
AVERAGE			0.42	0.54	0.89	0.21	0.28	0.42	0.38	0.68	0.38	0.11	0.08	0.24
10 cfs														
88.1	0.2	0.19	0.00	0.99	0.27	0.92	0.15	1.00	0.20	0.97	0.00	0.24	0.15	0.17
90.3	0.3	0.47	0.00	0.99	0.54	0.8	0.20	1.00	0.30	0.99	0.00	0.43	0.20	0.26
91.1	0.3	0.66	0.00	0.13	0.91	0.52	0.20	0.64	0.30	1.00	0.00	0.10	0.13	0.07
91.4	0.5	1.00	0.00	0.43	0.91	0.13	0.20	0.47	0.30	1.00	0.00	0.07	0.13	0.20
92.1	0.5	0.95	0.00	0.32	0.91	0.15	0.20	0.57	0.30	1.00	0.00	0.08	0.13	0.20
92.3	0.4	0.98	0.00	0.41	0.91	0.14	0.20	0.58	0.30	0.96	0.00	0.08	0.13	0.20
94.0	0.4	2.20	0.00	1.00	0.91	0.00	0.20	0.06	0.27	0.00	0.00	0.00	0.01	0.00
94.3	0.4	2.47	0.00	1.00	0.91	0.00	0.20	0.01	0.27	0.00	0.00	0.00	0.00	0.00
96.0	0.3	2.37	0.00	1.00	0.94	0.00	0.20	0.02	0.30	0.00	0.00	0.00	0.01	0.00
97.3	0.5	2.47	0.00	1.00	0.91	0.00	0.20	0.01	0.30	0.00	0.00	0.00	0.01	0.00
97.9	0.4	2.26	0.00	1.00	0.98	0.00	0.20	0.03	0.27	0.00	0.00	0.00	0.01	0.00
98.3	0.4	2.30	0.00	1.00	0.98	0.00	0.20	0.04	0.27	0.00	0.00	0.00	0.01	0.00
99.2	0.3	2.15	0.00	1.00	1.00	0.00	0.20	0.15	0.27	0.00	0.00	0.00	0.01	0.14
100.0	0.4	1.64	0.00	0.97	0.98	0.00	0.20	0.24	0.27	1.00	0.00	0.00	0.05	0.07
101.3	0.4	2.01	0.00	1.00	0.98	0.00	0.20	0.10	0.27	0.39	0.00	0.00	0.02	0.39
101.9	0.2	1.98	0.00	1.00	1.00	0.00	0.10	0.11	0.13	1.00	0.00	0.00	0.01	0.13
102.3	0.2	1.88	0.00	1.00	0.94	0.00	0.10	0.19	0.13	1.00	0.00	0.00	0.02	0.13
102.9	0.1	1.83	0.00	1.00	0.98	0.00	0.10	0.25	0.07	1.00	0.00	0.00	0.03	0.07
104.0	0.1	0.00	0.00	0.99	0.72	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
104.1	0.2	1.36	0.00	0.97	0.94	0.00	0.10	0.36	0.13	1.00	0.00	0.00	0.03	0.13
105.0	0.2	1.13	0.00	0.39	0.94	0.11	0.10	0.62	0.13	1.00	0.00	0.04	0.06	0.13
106.0	0.1	0.00	0.00	0.99	0.72	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
107.0	0.2	0.00	0.00	0.99	0.19	0.99	0.09	1.00	0.10	0.91	0.00	0.19	0.09	0.09
107.3	0.2	0.00	0.00	0.99	0.19	0.99	0.09	1.00	0.07	0.97	0.00	0.19	0.09	0.09
108.3	0.2	0.00	0.00	0.99	0.19	0.99	0.09	1.00	0.10	0.91	0.00	0.19	0.09	0.09
108.8	0.2	1.04	0.00	0.25	0.94	0.17	0.10	0.97	0.13	1.00	0.00	0.04	0.09	0.13
110.3	0.1	0.00	0.00	0.13	0.91	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
111.5	0.1	0.00	0.00	0.00	0.72	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
112.9	0.1	0.00	0.00	0.00	0.72	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
113.8	0.2	0.00	0.00	0.00	0.27	0.99	0.13	1.00	0.20	0.91	0.00	0.24	0.13	0.18
114.8	0.2	0.00	0.00	0.00	0.27	0.99	0.13	1.00	0.17	0.91	0.00	0.24	0.13	0.14
AVERAGE			0.00	0.44	0.95	0.44	0.14	0.62	0.19	0.75	0.00	0.10	0.09	0.14
3 cfs														
88.3	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
88.3	0.2	0.04	0.00	0.00	0.27	0.97	0.13	1.00	0.20	0.93	0.00	0.26	0.13	0.17
91.0	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
91.4	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
90.1	0.5	1.19	0.00	1.00	0.91	0.00	0.20	0.09	0.30	0.86	0.00	0.00	0.02	0.20
90.3	0.3	1.27	0.00	0.96	0.91	0.00	0.10	0.09	0.20	0.89	0.00	0.00	0.01	0.18
94.0	0.2	1.02	0.00	0.19	0.94	0.13	0.10	0.66	0.13	1.00	0.00	0.05	0.06	0.13
94.0	0.2	1.79	0.00	1.00	0.94	0.00	0.10	0.19	0.20	1.00	0.00	0.00	0.02	0.20
96.2	0.2	1.54	0.00	0.80	0.98	0.00	0.10	0.24	0.17	1.00	0.00	0.00	0.02	0.17
96.3	0.2	1.54	0.00	0.80	0.98	0.00	0.10	0.19	0.17	1.00	0.00	0.00	0.02	0.17
97.3	0.2	1.60	0.00	1.00	0.94	0.00	0.10	0.20	0.13	1.00	0.00	0.00	0.02	0.13
97.9	0.2	1.60	0.00	1.00	0.94	0.00	0.10	0.20	0.13	1.00	0.00	0.00	0.02	0.13
98.2	0.2	1.71	0.00	1.00	0.94	0.00	0.10	0.19	0.13	1.00	0.00	0.00	0.02	0.13
98.2	0.2	1.71	0.00	1.00	0.94	0.00	0.10	0.19	0.13	1.00	0.00	0.00	0.02	0.13
98.3	0.2	1.94	0.00	1.00	0.94	0.00	0.10	0.19	0.13	1.00	0.00	0.00	0.02	0.13
101.3	0.2	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.10	0.91	0.00	0.13	0.00	0.00
101.8	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.07	0.97	0.00	0.13	0.00	0.00
102.3	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
103.0	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
104.0	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
105.0	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
106.0	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
107.0	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
107.3	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
108.3	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
109.0	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
110.5	0.1	0.00	0.00	0.00	0.13	0.99	0.00	1.00	0.00	0.91	0.00	0.13	0.00	0.00
111.5	0.2	0.00	0.00	0.00	0.19	0.99	0.00	1.00	0.10	0.91	0.00	0.19	0.00	0.09
112.9	0.2	0.00	0.00	0.00	0.24	0.99	0.10	1.00	0.13	0.91	0.00	0.24	0.10	0.11
113.8	0.2	0.00	0.00	0.00	0.24	0.99	0.00	1.00	0.13	0.91	0.00	0.24	0.00	0.09
AVERAGE			0.00	0.26	0.91	0.45	0.09	0.73	0.11	0.87	0.00	0.08	0.05	0.10

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 2
TRANS 7

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
30 cfs														
73.0	<0.1	0.02	0.00	0.00	0.00	0.99	0.00	1.00	0.00	0.91	0.00	0.00	0.00	0.00
74.0	0.1	0.03	0.00	0.00	0.15	0.99	0.04	1.00	0.05	0.91	0.00	0.15	0.04	0.04
79.0	0.2	0.32	0.00	0.00	0.30	0.97	0.13	1.00	0.17	0.99	0.00	0.27	0.13	0.15
78.0	0.4	0.17	0.00	0.00	0.43	0.99	0.19	1.00	0.23	0.97	0.00	0.40	0.19	0.20
79.0	0.7	0.44	0.52	0.00	0.79	0.92	0.33	1.00	0.43	0.86	0.00	0.65	0.33	0.42
79.7	0.8	0.79	1.00	0.00	1.00	0.44	0.43	0.90	0.57	1.00	0.00	0.44	0.39	0.57
81.0	0.9	0.98	1.00	0.12	1.00	0.22	0.45	0.64	0.60	1.00	0.12	0.22	0.29	0.60
82.0	0.9	1.20	1.00	0.57	1.00	0.08	0.45	0.40	0.60	1.00	0.57	0.08	0.18	0.60
83.0	1.0	1.42	1.00	0.74	1.00	0.02	0.48	0.21	0.63	1.00	0.74	0.02	0.10	0.63
84.0	0.9	1.79	1.00	1.00	1.00	0.00	0.45	0.16	0.60	1.00	1.00	0.00	0.07	0.60
85.0	1.0	1.79	1.00	1.00	1.00	0.00	0.50	0.18	0.67	1.00	1.00	0.00	0.09	0.67
86.0	1.0	1.71	1.00	1.00	1.00	0.00	0.48	0.19	0.63	1.00	1.00	0.00	0.09	0.63
87.0	1.0	1.54	1.00	1.00	1.00	0.00	0.48	0.24	0.63	1.00	1.00	0.00	0.11	0.63
88.0	1.0	1.84	1.00	1.00	1.00	0.00	0.48	0.19	0.63	1.00	1.00	0.00	0.07	0.63
89.0	1.0	1.42	1.00	0.74	1.00	0.02	0.50	0.21	0.67	1.00	0.74	0.02	0.10	0.67
89.7	1.1	1.69	1.00	1.00	1.00	0.00	0.53	0.15	0.70	1.00	1.00	0.00	0.08	0.70
91.0	1.3	1.26	1.00	0.64	1.00	0.08	0.56	0.26	0.87	1.00	0.64	0.08	0.24	0.87
92.0	1.4	1.01	1.00	0.15	1.00	0.20	0.79	0.92	0.83	1.00	0.15	0.20	0.43	0.83
93.0	1.5	0.84	1.00	0.00	1.00	0.03	0.75	0.83	1.00	1.00	0.00	0.03	0.75	1.00
94.0	1.7	0.27	1.00	0.00	0.94	0.85	0.63	1.00	1.00	0.96	0.00	0.85	0.63	0.96
95.3	1.9	0.13	1.00	0.00	0.79	0.96	0.46	1.00	1.00	0.86	0.00	0.76	0.46	0.86
97.0	1.8	0.15	1.00	0.00	1.00	0.94	0.90	1.00	1.00	0.98	0.00	0.94	0.90	0.98
98.0	1.8	0.03	1.00	0.00	1.00	0.99	0.73	1.00	0.97	0.91	0.00	0.99	0.73	0.79
98.5	1.2	0.02	1.00	0.00	1.00	0.99	0.60	1.00	0.80	0.91	0.00	0.99	0.60	0.68
101.0	0.4	0.03	0.00	0.00	0.43	0.99	0.19	1.00	0.23	0.91	0.00	0.40	0.19	0.19
101.2	0.0	0.02	0.00	0.00	0.07	0.99	0.08	1.00	0.07	0.91	0.00	0.06	0.08	0.06
AVERAGE			0.75	0.34	0.83	0.52	0.47	0.87	0.81	0.93	0.34	0.34	0.31	0.58
10 cfs														
76.0	0.1	0.02	0.00	0.00	0.12	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.05
79.2	0.2	0.02	0.00	0.00	0.21	0.99	0.09	1.00	0.11	0.91	0.00	0.20	0.09	0.09
79.7	0.4	0.03	0.00	0.00	0.43	0.99	0.21	1.00	0.27	0.91	0.00	0.40	0.21	0.22
81.0	0.6	0.29	0.00	0.00	0.67	0.99	0.28	1.00	0.37	0.91	0.00	0.53	0.28	0.34
82.0	0.7	0.57	0.00	0.00	0.79	0.72	0.32	0.96	0.43	1.00	0.00	0.57	0.31	0.43
83.0	0.8	0.71	0.00	0.00	0.72	0.55	0.30	0.84	0.40	1.00	0.00	0.40	0.25	0.40
84.0	0.8	0.91	0.00	0.00	0.81	0.42	0.28	0.77	0.37	1.00	0.00	0.35	0.23	0.37
85.0	0.8	0.91	0.00	0.00	0.72	0.42	0.30	0.77	0.40	1.00	0.00	0.31	0.23	0.40
86.0	0.8	0.92	0.00	0.00	0.72	0.39	0.30	0.68	0.40	1.00	0.00	0.27	0.20	0.40
87.0	0.8	0.89	0.00	0.00	0.67	0.34	0.28	0.71	0.37	1.00	0.00	0.23	0.20	0.37
88.0	0.8	0.74	0.00	0.00	0.67	0.52	0.28	0.82	0.37	1.00	0.00	0.35	0.23	0.37
89.0	0.7	0.83	0.52	0.00	0.79	0.46	0.33	0.75	0.43	1.00	0.00	0.32	0.24	0.43
89.7	0.7	0.98	1.00	0.00	0.95	0.26	0.36	0.47	1.00	1.00	0.00	0.25	0.23	0.47
91.0	1.0	0.74	1.00	0.00	1.00	0.52	0.48	0.92	0.63	1.00	0.00	0.52	0.39	0.63
92.0	1.1	0.91	1.00	0.01	1.00	0.31	0.53	0.69	0.70	1.00	0.01	0.31	0.39	0.70
93.0	1.2	0.97	1.00	0.00	1.00	0.19	0.60	0.56	0.80	1.00	0.00	0.19	0.33	0.80
94.2	1.2	0.18	1.00	0.00	1.00	0.82	0.85	1.00	0.87	0.87	0.00	0.83	0.85	0.78
95.0	1.0	0.03	1.00	0.00	1.00	0.99	0.79	1.00	1.00	0.91	0.00	0.99	0.79	0.91
97.0	1.4	0.03	1.00	0.00	1.00	0.99	0.79	1.00	0.93	0.91	0.00	0.99	0.79	0.79
98.0	1.2	0.03	1.00	0.00	1.00	0.99	0.60	1.00	0.80	0.91	0.00	0.99	0.60	0.68
98.5	1.1	0.03	1.00	0.00	1.00	0.99	0.55	1.00	0.73	0.91	0.00	0.99	0.55	0.62
101.0	0.2	0.04	0.00	0.00	0.19	0.99	0.08	1.00	0.10	0.91	0.00	0.18	0.08	0.08
AVERAGE			0.45	0.01	0.74	0.69	0.38	0.90	0.50	0.92	0.00	0.50	0.34	0.46
5 cfs														
79.2	0.2	0.02	0.00	0.00	0.19	0.99	0.09	1.00	0.10	0.91	0.00	0.19	0.09	0.09
79.7	0.3	0.09	0.00	0.00	0.37	0.99	0.15	1.00	0.20	0.94	0.00	0.35	0.15	0.17
81.0	0.5	0.24	0.00	0.00	0.55	0.91	0.23	1.00	0.30	0.99	0.00	0.50	0.23	0.27
82.0	0.5	0.37	0.00	0.00	0.61	0.85	0.25	1.00	0.33	0.96	0.00	0.52	0.25	0.30
83.0	0.5	0.41	0.00	0.00	0.61	0.84	0.25	1.00	0.33	0.94	0.00	0.51	0.25	0.30
84.0	0.5	0.48	0.00	0.00	0.61	0.80	0.25	1.00	0.33	1.00	0.00	0.48	0.25	0.30
85.0	0.5	0.47	0.00	0.00	0.61	0.81	0.25	1.00	0.33	0.98	0.00	0.50	0.25	0.33
86.0	0.5	0.57	0.00	0.00	0.61	0.73	0.25	0.95	0.33	1.00	0.00	0.44	0.24	0.33
87.0	0.5	0.54	0.00	0.00	0.61	0.75	0.25	0.97	0.33	1.00	0.00	0.46	0.24	0.33
88.0	0.5	0.44	0.00	0.00	0.61	0.82	0.25	1.00	0.33	0.98	0.00	0.48	0.25	0.32
89.0	0.5	0.57	0.00	0.00	0.61	0.73	0.25	0.95	0.33	1.00	0.00	0.44	0.24	0.33
89.7	0.6	0.64	0.00	0.00	0.72	0.62	0.26	0.90	0.40	1.00	0.00	0.45	0.27	0.40
91.0	0.8	0.49	1.00	0.00	1.00	0.80	0.43	1.00	0.57	1.00	0.00	0.80	0.43	0.56
92.0	1.0	0.58	1.00	0.00	1.00	0.69	0.52	0.93	0.67	1.00	0.00	0.69	0.47	0.67
93.0	1.1	0.44	1.00	0.00	1.00	0.82	0.55	1.00	0.73	0.98	0.00	0.82	0.55	0.73
94.2	1.2	0.20	1.00	0.00	1.00	0.92	0.70	1.00	0.90	0.88	0.00	0.83	0.69	0.79
95.0	1.0	0.03	1.00	0.00	1.00	0.99	0.75	1.00	1.00	0.91	0.00	0.99	0.75	0.91
97.0	1.3	0.11	1.00	0.00	1.00	0.96	0.63	1.00	0.83	0.96	0.00	0.96	0.63	0.79
98.0	1.0	0.03	1.00	0.00	1.00	0.99	0.50	1.00	0.67	0.91	0.00	0.99	0.50	0.64
98.5	1.0	0.02	1.00	0.00	1.00	0.99	0.50	1.00	0.99	0.91	0.00	0.99	0.50	0.64
101.0	0.1	0.02	0.00	0.00	0.13	0.99	0.06	1.00	0.07	0.91	0.00	0.12	0.06	0.06
AVERAGE			0.38	0.00	0.71	0.89	0.36	0.98	0.48	0.96	0.00	0.50	0.34	0.45

J-728 Alameda Creek
Habitat suitability index ratings for depth and velocity at three flow regimes.

REACH 2
TRANS 8

	DEPTH	VELOCITY	HABITAT SUITABILITY VALUES								COMBINED DEPTH AND VELOCITY			
			SPAWNING		FRY		JUVENILE		ADULT					
DIST	(ft)	(ft/s)	Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity	SPAWN	FRY	JUV	ADULT
10 cfs														
00.0	0.1	0.03	0.00	0.00	0.09	0.99	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
29.0	0.1	0.03	0.00	0.00	0.09	0.99	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
30.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
30.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
30.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
34.0	0.9	0.03	0.00	0.00	0.99	0.99	1.00	1.00	0.99	0.91	0.00	0.00	0.00	0.00
36.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
36.0	0.3	1.15	0.00	0.28	0.37	0.14	0.15	0.51	0.20	1.00	0.00	0.05	0.08	0.20
39.0	0.2	1.52	0.00	0.08	0.24	0.00	0.10	0.24	0.13	1.00	0.00	0.00	0.00	0.13
39.0	0.2	0.51	0.00	0.51	0.24	0.31	0.10	0.99	0.13	1.00	0.00	0.08	0.07	0.13
41.0	0.2	1.54	0.00	0.02	0.24	0.00	0.10	0.24	0.13	1.00	0.00	0.00	0.00	0.13
42.0	0.3	0.99	0.00	0.00	0.37	0.00	0.15	0.99	0.20	1.00	0.00	0.00	0.13	0.20
44.0	0.3	0.94	0.00	0.00	0.24	0.53	0.10	0.90	0.13	1.00	0.00	0.15	0.09	0.13
46.0	0.2	0.00	0.00	0.00	0.20	0.99	0.13	1.00	0.17	0.91	0.00	0.20	0.13	0.14
47.0	0.6	1.48	0.00	0.71	0.55	0.04	0.23	0.33	0.30	1.00	0.00	0.02	0.07	0.30
48.0	0.4	0.71	0.00	0.00	0.49	0.52	0.20	0.94	0.27	1.00	0.00	0.27	0.17	0.27
49.0	0.9	0.38	0.00	0.00	0.87	0.94	0.79	1.00	0.97	0.96	0.00	0.84	0.28	0.36
51.0	0.7	0.02	1.00	0.00	0.96	0.99	0.35	1.00	0.47	0.91	0.00	0.94	0.35	0.38
52.0	0.9	0.38	1.00	0.00	0.99	0.85	0.40	1.00	0.53	0.96	0.00	0.92	0.40	0.51
53.0	1.0	0.82	1.00	0.00	1.00	0.40	0.50	0.73	0.67	1.00	0.00	0.40	0.37	0.67
54.0	1.3	1.09	1.00	0.25	1.00	0.17	0.63	0.57	0.83	1.00	0.25	0.17	0.36	0.83
55.0	1.3	0.91	1.00	0.01	1.00	0.31	0.66	0.80	0.87	1.00	0.01	0.31	0.45	0.87
56.0	1.5	0.79	1.00	0.00	1.00	0.40	0.75	0.90	1.00	1.00	0.00	0.40	0.60	1.00
57.0	1.5	0.60	1.00	0.00	1.00	0.40	0.75	0.75	1.00	1.00	0.00	0.40	0.54	1.00
58.0	1.4	0.42	1.00	0.00	1.00	0.82	0.70	1.00	0.93	0.97	0.00	0.82	0.70	0.90
59.0	0.3		0.00	0.00	0.37	1.00	0.15	1.00	0.20	0.90	0.00	0.37	0.15	0.18
AVERAGE			0.31	0.13	0.48	0.63	0.26	0.82	0.34	0.92	0.01	0.27	0.20	0.30
5 cfs														
28.0	0.0	0.03	0.00	0.00	0.01	0.99	0.01	1.00	0.01	0.91	0.00	0.01	0.01	0.01
29.0	0.1	0.03	0.00	0.00	0.09	0.99	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
30.0	0.1	0.03	0.00	0.00	0.09	0.99	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
31.0	0.7	0.03	1.00	0.00	0.99	0.99	1.00	1.00	1.00	0.91	0.00	0.00	1.00	0.91
32.0	0.1	0.03	0.00	0.00	0.09	0.99	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
33.0	0.1	0.03	0.00	0.00	0.09	0.99	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
34.0	0.1	0.03	0.00	0.00	0.09	0.99	0.03	1.00	0.03	0.91	0.00	0.09	0.03	0.03
34.0	0.1	0.03	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
36.0	0.3	1.13	0.00	0.32	0.24	0.15	0.10	0.53	0.13	1.00	0.00	0.04	0.06	0.13
36.0	0.2	1.03	0.00	0.19	0.24	0.19	0.10	0.60	0.13	1.00	0.00	0.06	0.06	0.13
41.0	0.2	0.87	0.00	0.00	0.19	0.72	0.08	0.86	0.10	1.00	0.00	0.13	0.07	0.10
42.0	0.3	0.03	0.00	0.00	0.24	0.99	0.15	1.00	0.13	0.91	0.00	0.24	0.15	0.11
44.0	0.5	0.02	0.00	0.00	0.13	0.99	0.05	1.00	0.07	0.91	0.00	0.13	0.05	0.06
46.0	0.3	0.09	0.00	0.00	0.20	0.97	0.13	1.00	0.17	0.83	0.00	0.20	0.13	0.14
47.0	0.3	0.20	0.00	0.00	0.37	0.92	0.15	1.00	0.20	0.98	0.00	0.34	0.15	0.19
48.0	0.3	0.91	0.00	0.01	0.37	0.31	0.15	0.62	0.20	1.00	0.00	0.11	0.10	0.20
49.0	0.5	0.00	0.00	0.00	0.52	0.99	0.23	1.00	0.30	0.91	0.00	0.54	0.23	0.24
51.0	0.8	0.03	0.00	0.00	0.67	0.99	0.29	1.00	0.37	0.91	0.00	0.66	0.28	0.30
52.0	0.7	0.25	1.00	0.00	0.96	0.90	0.35	1.00	0.47	0.96	0.00	0.77	0.35	0.42
53.0	0.8	0.49	1.00	0.00	1.00	0.80	0.45	1.00	0.60	1.00	0.00	0.80	0.45	0.60
54.0	1.1	0.64	1.00	0.00	1.00	0.62	0.56	0.96	0.73	1.00	0.00	0.62	0.48	0.73
55.0	1.2	0.81	1.00	0.00	1.00	0.46	0.58	0.91	0.77	1.00	0.00	0.46	0.52	0.77
56.0	1.4	0.91	1.00	0.00	1.00	0.34	0.70	0.81	0.93	1.00	0.00	0.34	0.54	0.93
57.0	1.3	0.40	1.00	0.00	1.00	0.82	0.66	1.00	0.87	0.98	0.00	0.82	0.66	0.85
58.0	1.2	0.15	1.00	0.00	1.00	0.94	0.60	1.00	0.80	0.94	0.00	0.94	0.60	0.69
59.0	0.3	0.02	1.00	0.00	0.00	0.99	1.00	1.00	1.00	0.91	0.00	0.00	1.00	0.91
60.0	0.3	0.03	0.00	0.00	0.20	0.99	0.13	1.00	0.17	0.91	0.00	0.20	0.13	0.14
AVERAGE			0.33	0.03	0.40	0.82	0.26	0.94	0.35	0.98	0.00	0.32	0.27	0.32

APPENDIX C.

METEOROLOGICAL CONDITIONS RECORDED AT CALAVERAS DAM DURING THE STUDY PERIOD

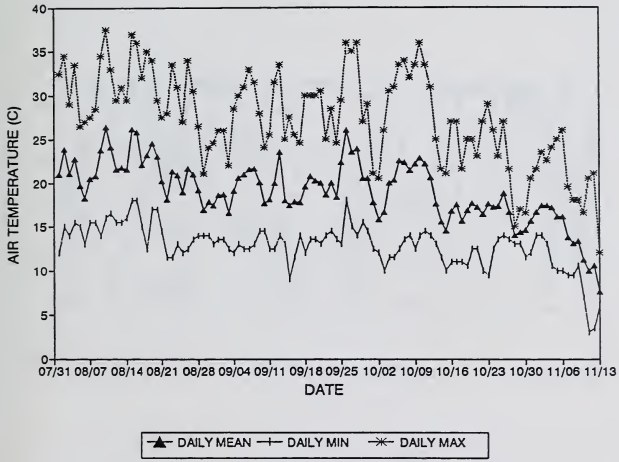


Figure C-1. Daily mean, minimum, and maximum air temperature (C) recorded at Calaveras Dam, August - November 1992 (BioSystems Meteorological Station).

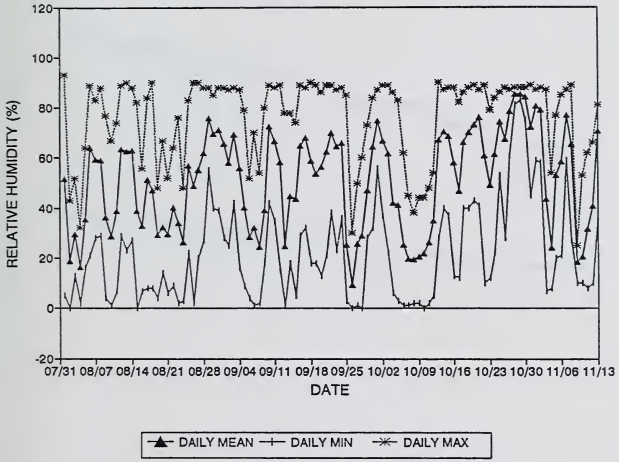


Figure C-2. Daily mean, minimum, and maximum relative humidity (%) recorded at Calaveras Dam, August - November 1992 (BioSystems Meteorological Station).

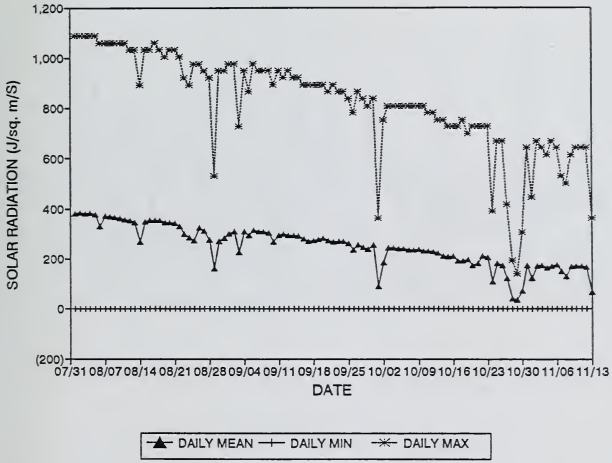


Figure C-3. Daily mean, minimum, and maximum solar radiation (J/sq. m/S) recorded at Calaveras Dam, August - November 1992 (BioSystems Meteorological Station).

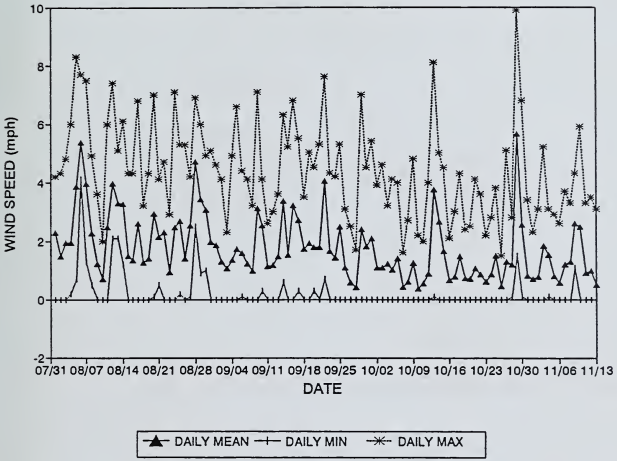


Figure C-4. Daily mean, minimum, and maximum wind speed (mph) recorded at Calaveras Dam August - November 1992 (BioSystems Meteorological Station).

APPENDIX F

REPORT ON WATERSHED OPERATIONS JUNE 1994

ALAMEDA CREEK
WATER RESOURCES STUDY

REPORT ON
WATERSHED OPERATIONS

PREPARED FOR

SAN FRANCISCO WATER DEPARTMENT

PREPARED BY
BOOKMAN-EDMONSTON
ENGINEERING, INC.

Unpublished Work © June 1994

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CHAPTER 1 INTRODUCTION

Recognizing that the opportunity may exist for modifying district operations to enhance fisheries in portions of Calaveras and Alameda Creeks, the San Francisco Water Department (SFWD) is conducting the Alameda Creek Water Resources Study. This study reviews methods for possibly changing SFWD operations to release water to portions of Calaveras and Alameda Creeks downstream of Calaveras Dam. The additional flows would provide for improved fisheries conditions in several downstream stream reaches. The released water would be recaptured downstream through the existing Sunol Filter Galleries or through new facilities, such as a wellfield or dam.

Concurrent with fisheries and recapture studies, an overall water management plan is being developed to identify opportunities for increased water supply through changed operations policies. The results of the Alameda Creek Water Resources Study are summarized in the SFWD report *Alameda Creek Water Resources Study*, which will be released at a later date. This report on hydrologic studies serves as one of the appendices to the Alameda Creek Water Resources Study report and documents the results of supporting hydrologic studies.

The hydrologic studies quantify the regulated water supply that can be provided by the Alameda Creek watershed. These hydrologic studies consider the natural runoff of the watershed and the operations of SFWD facilities which regulate this runoff.

The goals of the hydrologic studies were to:

- Evaluate the potential for increased water supply through coordinated operation of Alameda Creek facilities.
- Identify the adequacy of available water supplies for maintaining fisheries releases.
- Identify potential increases in yield through conjunctive operation of the Sunol Valley Groundwater Basin together with Alameda Creek surface water facilities.

To concentrate on these goals, the hydrologic studies have been focussed primarily on SFWD's Alameda Creek watershed facilities and did not directly consider possible coordination with Hetch Hetchy Aqueduct operation. Hetch Hetchy supplies and their impacts are, however, discussed for historical operations and are reviewed qualitatively for the constraints that they impose on Alameda Creek operations.

The hydrologic studies began with the estimation of natural runoff that occurs in individual portions of the Alameda Creek watershed. Runoff estimates were combined with information on the capacity of SFWD facilities and their operational procedures to develop

a computer operation model. Several possible management alternatives were developed that are described in more detail in the companion Bookman-Edmonston *Report on Water Recovery Facilities*. Use of the completed operation model to simulate selected management alternatives is described in the final section of this report.

CHAPTER 2 STREAMFLOW

The basic data needed for hydrologic studies of the Alameda Creek watershed are streamflow estimates for individual drainages. Ideally, streamflows can be quantified from direct measurements. In Alameda Creek, however, direct measurements are not available for the required locations or periods. When such direct measurements are not available, estimates must be developed based on indirect factors such as precipitation, drainage area, and runoff on nearby watersheds. This chapter describes the analysis that was conducted to provide consistent estimates of streamflow in individual Alameda Creek Watershed drainages for the 1918 through 1990 study period. The description begins with a review of historical measurements in Alameda Creek and continues with a description of the specific methods used to update streamflow data.

HISTORICAL ANALYSIS

Early estimates of streamflow on individual portions of the Alameda Creek watershed were prepared by the Spring Valley Water Company (SVWC) in the 1912 report *The Future Water Supply of San Francisco.* These initial estimates were based on very limited experience in measuring streamflow in the Alameda Creek watershed. In 1912, flow records were available for the entire Alameda Creek watershed for water years 1889-1890 to 1907-1908 at a location equivalent to Niles Dam. SVWC's estimate of Alameda Creek runoff during that period averaged 132 million gallons per day (mgd), or 147,860 acre-feet per year. The amount of flow for the entire Alameda Creek watershed was assigned to individual watersheds, based primarily on flow records for Calaveras Creek for the water years 1898-1899 through 1902-1903 and for the water years 1904-1905 through 1907-1908. Additional flow records were also available for the Arroyo Valle watershed for the years 1904-1905 through 1907-1908. SVWC estimated the proportion of the entire Alameda Creek flow at Niles that originated in individual watersheds. This was based on the available Calaveras Creek and Arroyo Valle streamflow gagings and available information on watershed area, rainfall amounts, topography and soil characteristics. In this manner, the average inflow directly into Calaveras Reservoir was estimated to be 58 mgd, or 65,000 acre-feet per year. Estimated inflow at the Alameda Creek Diversion Dam site was 10 mgd, or 11,200 acre-feet per year and runoff in the remaining watersheds contributing to the Sunol Valley was estimated at about 15 mgd, or 16,840 acre-feet per year. The estimate of local runoff to Sunol Valley includes San Antonio Creek and several other watersheds, such as Sinbad and Vallecitos Creeks. Both Sinbad and Vallecitos Creeks flow into Alameda Creek below the Sunol Water Temple and do not necessarily contribute to supplies at the Sunol Filter Galleries.

SVWC continued measuring streamflows at the Calaveras Creek dam site and also at dam sites on Alameda Creek and La Costa (San Antonio) Creek until 1930. The locations of these gaging sites are shown in Figure 1. The average annual inflow at the Calaveras Creek site between water years 1898 and 1912 was 50,700 acre-feet. Beginning in 1913, construction activities began at the Calaveras Creek dam site resulting in occasional regulation of streamflows. Initially, regulation at the dam site was very minor. However, by 1914, regulation of Calaveras Creek streamflows increased significantly and resulted in a shift of the seasonal pattern of flows. As a result, significant flows were released during summer months when flows had previously been inconsequential. The SVWC flow estimates between 1913 and 1930 are not directly usable for analysis, due to the uncertain amount of storage regulation that occurred in that period.

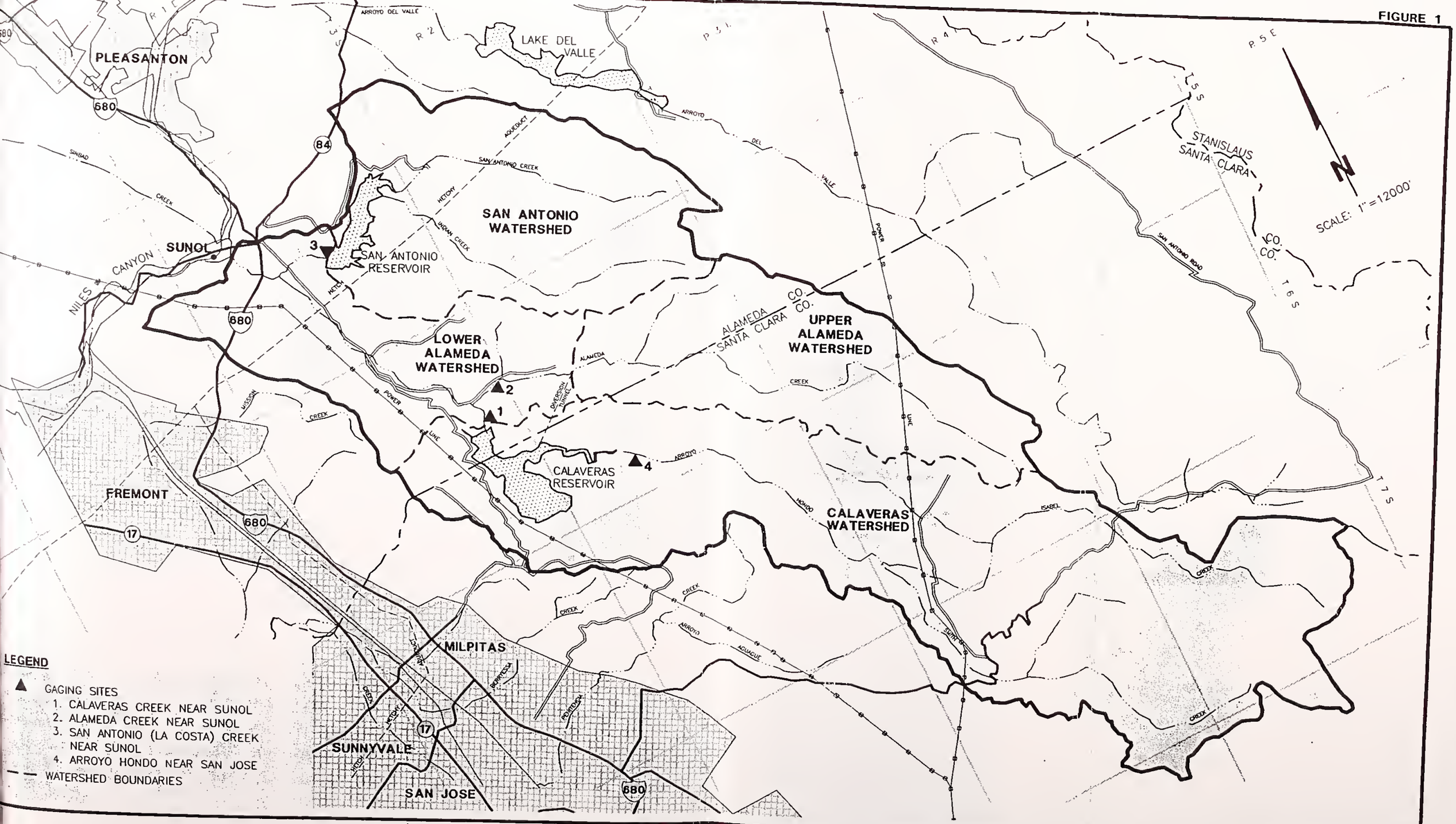
Measured Alameda Creek flows at the Alameda Diversion Dam site averaged 13,050 acre-feet per year between 1912 and 1930. Flows at the San Antonio dam site on La Costa Creek averaged 8,080 acre-feet per year between 1913 and 1930. Monthly summaries of the SVWC flow measurements are included in Appendix A, Tables A1 through A3.

STUDY ESTIMATES

SVWC and SFWD have maintained records of water production from the Calaveras and San Antonio Reservoirs since water management facilities were constructed on Alameda Creek watershed in the early 1900s. Water production is defined as the combination of water supply discharges and increase in reservoir storage. Reservoirs spills are not included in the water production estimates and are typically not estimated. For Calaveras Reservoir, where runoff from the local watersheds (either directly or through the Alameda Creek Diversion Dam) is the only source of supply, SFWD water production estimates were adjusted for evaporation losses to provide an estimate of inflow during nonspill periods. For the San Antonio Reservoir, the quantity of local inflow is relatively small compared to the large quantities of Hetch Hetchy supplies stored in the reservoir. An estimate of San Antonio inflow was developed through adjustment for evaporation, Hetch Hetchy Aqueduct inflows, and imports from the South Bay Aqueduct. These estimates are especially subject to error since relatively slight errors in large quantities of Hetch Hetchy diversions to the reservoir could be larger than the entire amount of San Antonio local inflow, especially during dry periods. However, the San Antonio local flow estimates were reasonably confirmed through correlation with other streamflow records, as discussed later.

To provide usable estimates of local inflow in the Alameda Creek watershed for the entire study period, a combination of data sources were referenced. Initially, estimates of inflow to Calaveras Reservoir were developed based on recorded U. S. Geological Survey (USGS) measurements at the Arroyo Hondo gage near San Jose. This gage is located upstream of Calaveras Reservoir and measures runoff from a 77.1-square-mile watershed, about 78 percent of the watershed contributing directly to Calaveras Reservoir. The USGS

FIGURE 1



LEGEND

- ▲ GAGING SITES
  1. CALAVERAS CREEK NEAR SUNOL
  2. ALAMEDA CREEK NEAR SUNOL
  3. SAN ANTONIO (LA COSTA) CREEK NEAR SUNOL
  4. ARROYO HONDO NEAR SAN JOSE
- — — WATERSHED BOUNDARIES

ALAMEDA CREEK WATER RESOURCES STUDY

WATERSHED BOUNDARIES AND GAGING STATIONS

SAN FRANCISCO WATER DISTRICT

BOOKMAN–EDMONSTON ENGINEERING INC.

DECEMBER 1993

measured flows at the Arroyo Hondo gage from 1969 until the gaging site was discontinued after 1981. The monthly USGS flow measurements for the Arroyo Hondo gage are summarized in Appendix A, Table A4. Estimates of Calaveras Dam inflow were developed for the 1969 through 1981 water years through adjustment of Arroyo Hondo flows for differences in drainage area. The Arroyo Hondo gage was then correlated with several other nearby streams with longer periods of record to extend the record for the 1918 through 1991 study period. The best correlation with a gaging station with long-term records was achieved with the Stevens Creek near Cupertino gage. This correlation was used to extend Arroyo Hondo flow measurements for the entire study period. Estimates of Calaveras Dam inflow (excluding diversions from Alameda Creek) were developed for the study period through adjustments of observed and estimated Arroyo Hondo flows for differences in drainage area and average annual watershed precipitation (Hannaford, 1993).

Natural streamflow runoff was then estimated for other watersheds, shown in Figure 1. These streamflow runoff estimates were based on the Arroyo Hondo data and available SFWD or SVWC records with adjustments for drainage area, average annual watershed precipitation, and estimated watershed losses. For San Antonio Creek runoff, the streamflow records estimated in this manner were compared to SFWD water production estimates, particularly for peak runoff periods when local runoff was significant and for periods of small watershed import amounts. On average, San Antonio Creek inflow estimated from Arroyo Hondo flows reasonably matched adjusted water production amounts.

The estimated streamflows are summarized graphically in Figure 2 and tabulated in Appendix A, Tables A5 through A8. For the 1918 through 1992 study period, average natural runoff in the Alameda Creek watershed above Sunol is 59,700 acre-feet. The largest component of this runoff is the direct inflow to Calaveras Reservoir, which is estimated to average 36,000 acre-feet per year. Flows at the Alameda Creek Diversion Dam averaged 12,000 acre-feet and flows at the San Antonio dam site averaged 7,200 acre-feet per year. Local runoff below these facilities averaged 4,500 acre-feet per year.

All the watersheds in Alameda Creek have seasonal variations that are typical of the Coast Ranges. Nearly all flows are derived from rainfall and high flows directly follow periods of high rainfall. Typically, flows in Alameda Creek watersheds are high in winter months when rainfall occurs and are extremely low during summer. Figure 3 shows the average monthly runoff amounts for Calaveras Reservoir direct inflow, which are typical of other watersheds. The highest flow amounts occur, on average, during January, February, and March. Average flows diminish from April through June, and only incidental flow amounts of less than 2 cfs occur from July through October.

Figure 2
Alameda Creek Watershed Natural Runoff

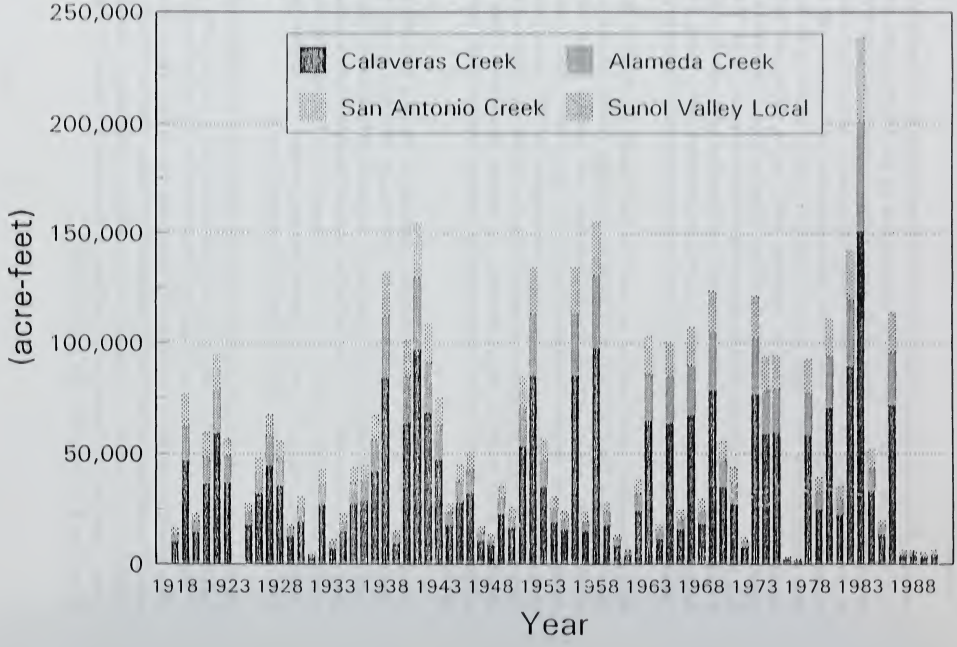
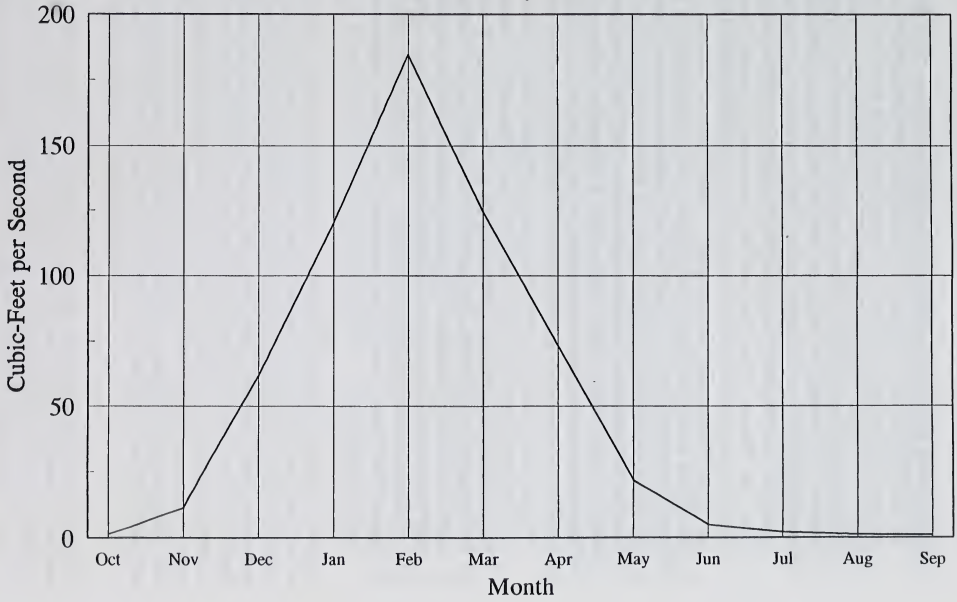


Figure 3
Calaveras Reservoir Direct Inflow
Average Estimated Monthly Flow -- 1918-1990



An additional analysis was required for quantities of Alameda Creek diversions at the Alameda Diversion Dam. The Alameda Tunnel has an estimated capacity of 3,000 cubic feet per second (cfs) which, on a monthly average basis, would allow diversion of nearly all flows of the creek. However, actual flows in Alameda Creek occasionally have instantaneous peaks in excess of 3,000 cfs, and the Diversion Dam is typically unable to divert the entire amount of Alameda Creek flows and passes portions of these flows downstream in the Alameda Creek channel. The Diversion Dam has historically been operated to pass storms with large quantities of debris, typically the first flood event of a water year. Because of these considerations, the amount of potential diversions from the Alameda Creek Diversion Dam was estimated based on estimated daily flow records from the Arroyo Hondo near San Jose gage. Several levels of diversion capacity were investigated for the 1969 through 1981 period. Monthly diversions were estimated from analysis of the daily records, added to the estimated direct inflow to Calaveras Reservoir, and plotted against the calculated inflow from SFWD water production records. The comparison of estimated Calaveras Reservoir inflow from both methods was very close, except for periods where spill was not included in the adjusted water production records. Daily flows from several nearby watersheds were adjusted for average annual precipitation and used to estimate the monthly diversion potential from the Upper Alameda Creek Diversion Dam (Hannaford, 1993). The quantity of Upper Alameda watershed flows that could not be diverted was considered to be spills and is tabulated in Appendix A, Table A9. The estimated average annual spills during the study period is 2,800 acre-feet, and the corresponding estimate of Alameda Creek flows that could have been diverted is 9,200 acre-feet (12,000 - 2,800). The estimate of potential Alameda Creek diversions considered only the physical diversion capability of the Alameda Creek Diversion Dam and was not limited by Calaveras Reservoir storage considerations. When Calaveras Reservoir is at or near capacity, SFWD may choose not to divert flows into Calaveras Reservoir if there is no available storage space.

CHAPTER 3 SFWD FACILITIES AND OPERATIONS

The facilities that currently regulate streamflows in the Alameda Creek south of Sunol have been developed over the past nearly 100 years by the SFWD and its predecessor, the SVWC. This chapter provides a brief historical overview of the development of Alameda Creek facilities, a quantitative summary of the physical characteristics of existing facilities, and a data review and summary of recent operations in the Alameda Creek watershed.

HISTORICAL DEVELOPMENT

SVWC's active involvement in the Alameda Creek watershed began in 1875 when it purchased the water rights of Vallejo Mills (SVWC, 1912). In addition to the Vallejo Mills water rights, SVWC purchased land at two sites, one on Alameda Creek at the mouth of Niles Canyon (near Vallejo Mills) and the other at the Calaveras Reservoir dam site. SVWC continued to purchase water rights and land in the Alameda Creek watershed after 1875. In 1887 and 1888, the original Alameda Creek diversion works were completed at Niles, allowing diversions of Alameda Creek flows for delivery from the Transbay Pipeline at the Dumbarton Strait to San Francisco.

SVWC constructed the Sunol Dam in 1899. The original purpose of this dam was to provide an upstream point of diversion for Alameda Creek flows which would minimize the potential for water quality contamination in Niles Canyon from recreational usage. All SVWC operations prior to 1900 were dependent on naturally occurring streamflows in Alameda Creek without the benefit of significant regulatory storage. Streamflows were captured as diversion capacity and flows were available with large variations in both seasonal and annual diversions due to wetness conditions.

In 1900 and 1901, additional construction was completed by SVWC to raise Sunol Dam and construct the Sunol Filtration Gallery and Water Temple. The raising of Sunol Dam had the effect of raising the discharge elevation of Sunol Valley groundwater and resulted in general rises in groundwater in large portions of the Sunol Valley. These increased groundwater levels were then drained by the subsurface Sunol Filtration Galleries and could be delivered directly through the Niles Aqueduct to the Transbay Pipeline. This mode of operation, which captured water at the Filter Galleries, provided SVWC with greater control of water supplies, and naturally filtered Alameda Creek supplies, resulting in a higher quality than unfiltered surface water. The Filter Galleries, while not necessarily increasing the quantities of water supplies, provided higher quality water.

Beginning in 1901, the SVWC developed groundwater wells in its Pleasanton wellfield for additional water supplies. Initially, pumped groundwater from the Pleasanton wellfields was delivered through the channel of Arroyo de la Laguna to the Sunol Filter Galleries. In 1909, a pipeline was completed from the Pleasanton wellfield that allowed direct supply to

a collection point at the Sunol Water Temple, where pumped groundwater intermingled with Sunol Valley groundwater captured by the Sunol Filter Galleries. The Pleasanton wellfield produced a dependable source of supply without the dramatic seasonal and year-to-year variations in Alameda Creek streamflows.

Because of the large variations in Alameda Creek streamflows, the SVWC began planning for regulatory storage to capture wet year flows for later use. Two primary storage sites were identified in the Alameda watershed south of Sunol, Calaveras Reservoir and San Antonio Reservoir. The Calaveras Reservoir site was especially attractive, due to its large potential capacity and the quantity of available flows at the site. Construction on Calaveras Dam began in 1913 using the hydraulic fill method of construction. Storage at Calaveras began in March 1916 with closing of gates on the dam. In March 1918, a large slide (700,000 cubic yards) occurred on the upstream face of the dam. The dam was completed using the rolled fill method in 1925. With completion of Calaveras Reservoir, high flows on Calaveras Creek could be captured in the winter months of wet years and provide carryover reserves for multiyear droughts. Water released from Calaveras Reservoir at controlled rates would percolate into the Sunol groundwater basin and was recaptured in the Sunol Filter Galleries.

Construction of the Upper Alameda Diversion Dam and a tunnel to Calaveras Reservoir began in 1925 and was completed in 1931. These two facilities allowed diversion into Calaveras Reservoir of the bulk of flow on the main stem of Alameda Creek, increasing the total supply provided by Calaveras Reservoir. In 1930, the City and County of San Francisco purchased SVWC, and the SFWD became responsible for operating former SVWC facilities.

With completion of the Hetch Hetchy Aqueduct in 1934, additional facilities were constructed to directly deliver Calaveras Reservoir supplies to the Aqueduct. An aerator was built at the base of Calaveras Reservoir, and the Calaveras Pipeline was built between Calaveras Reservoir and the Hetch Hetchy Aqueduct. With completion of these facilities, streamflows below the reservoir were limited to spill periods, dam seepage, and inflow from unregulated tributaries. Inflow to the Filter Galleries was diminished. Export pumpage from SFWD's Pleasanton Wellfield also ceased after the 1930s with availability of Hetch Hetchy supplies except for 15 months during the 1948-1949 drought (DWR, 1963). The Sunol Filter Galleries diverted relatively small amounts of Sunol Valley groundwater that was recharged by local runoff of small watersheds below Calaveras Reservoir and by spills from the reservoir. During high flow periods, gravel dams were frequently constructed in the Alameda Creek channel to increase seepage directly into the Filter Galleries, which continued a practice of the SVWC.

The remaining facilities in the Alameda Creek watershed, including San Antonio Reservoir, the Sunol Filtration Plant, Sunol Pumping Plant, and the San Antonio Pumping Plant, were constructed by the SFWD in the mid-1960s. San Antonio Reservoir was completed in 1965

to provide regulatory storage for Hetch Hetchy Aqueduct, local San Antonio Creek runoff, and Sunol Filter Gallery supplies. The construction of San Antonio Reservoir further reduced Sunol Valley streamflow and flows to the Sunol Filter Galleries. Groundwater collected in the Sunol Filter Galleries could be pumped through the Sunol and San Antonio Pumping Plants, either for storage in San Antonio Reservoir or for treatment at the Sunol Filtration Plant. The San Antonio Pumping Plant also provides the capability to move water from Hetch Hetchy Aqueduct to San Antonio Reservoir and from San Antonio Reservoir to the Sunol Filtration Plant. The Sunol Filtration Plant provides increased levels of water treatment for Calaveras and San Antonio Reservoir releases. Connection of Calaveras Pipeline to San Antonio Reservoir allows flow by gravity from Calaveras Reservoir to San Antonio Reservoir during periods when storage space at San Antonio Reservoir is available.

Most recently, the Calaveras Pipeline was replaced in 1991, and an aerator was installed in Calaveras Reservoir to improve water quality conditions at the same time. Reservoir characteristics for Calaveras and San Antonio Reservoirs are summarized in Table 1 and their area capacity curves are presented in Table 2.

Table 1
RESERVOIR CHARACTERISTICS

	Calaveras	San Antonio
Drainage Area	100 (135*)	39.7
Capacity	98,823 acre-feet	50,500 acre-feet
Spillway Capacity	22,000 cfs	13,500 cfs
Spillway Elevation	753.46 feet above MSL	468 feet above MSL
Outlet Intake Elevations	729, 699, 664, and 603 feet above MSL	436, 406, 376, 346, and 316 feet above MSL

*Including area tributary to Alameda Creek Diversion Dam.

Table 2
RESERVOIR AREA CAPACITY TABLES

Calaveras Reservoir					San Antonio Reservoir				
Stage (ft.)	Storage		Area		Stage (ft.)	Storage		Area	
	(mg)	(ac-ft)	(ft^2)	(acres)		(mg)	(ac-ft)	(ft^2)	(acres)
615	150	460	2,004,000	46	370	1,630	5,002	3,350,276	77
625	470	1,442	4,275,200	98	380	2,280	6,997	8,684,000	199
635	1,000	3,069	7,080,800	163	390	3,080	9,452	10,688,000	245
645	1,790	5,493	10,654,400	245	400	4,070	12,490	13,226,400	304

Table 2
RESERVOIR AREA CAPACITY TABLES

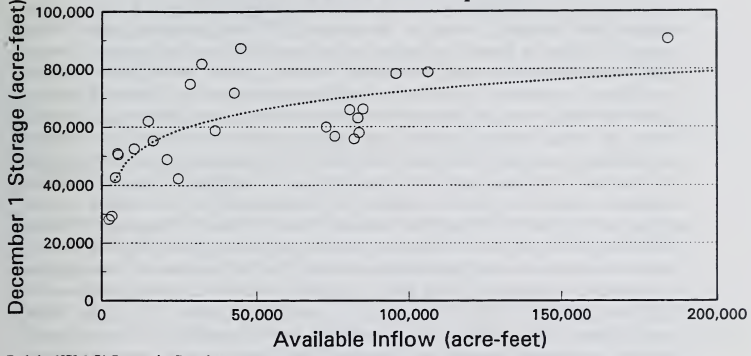
Calaveras Reservoir					San Antonio Reservoir				
Stage (ft.)	Storage		Area		Stage (ft.)	Storage		Area	
	(mg)	(ac-ft)	(ft^2)	(acres)		(mg)	(ac-ft)	(ft^2)	(acres)
655	2,850	8,746	14,161,600	325	410	5,280	16,204	16,165,600	371
665	4,220	12,951	18,303,200	420	420	6,580	20,193	17,368,000	399
675	5,960	18,290	23,246,400	534	430	8,140	24,981	20,841,600	478
685	8,090	24,827	28,456,800	653	440	9,800	30,075	22,177,600	509
695	10,590	32,499	33,400,000	767	450	11,890	36,489	27,922,400	641
705	13,420	41,184	37,808,800	868	460	14,340	44,008	32,732,000	751
715	16,590	50,913	42,351,200	972	468	16,450	50,438	35,237,000	809
725	20,110	61,715	47,027,200	1,080					
735	23,980	73,592	51,703,200	1,187					
745	28,190	86,511	56,245,600	1,291					
753	31,560	96,854	60,030,900	1,378					

HISTORICAL OPERATION

To provide a starting point for describing operation of SFWD facilities in the Alameda Creek watershed, historical operations of the facilities were obtained and reviewed. Calaveras Reservoir operations are summarized graphically in Figure A-1 of Appendix A. The top portion of this figure shows historical beginning-of-month storage quantities and the bottom portion shows amounts of water supply releases. Calaveras Reservoir operations are described in some detail, since they are dependent on local runoff conditions that can be reasonably simulated for an Alameda Creek-only operations study. San Antonio Reservoir operations are also described later at a lesser degree of detail, since they are dominated by storage of Hetch Hetchy supplies and are variable on a daily or hourly basis due to immediate water supply conditions.

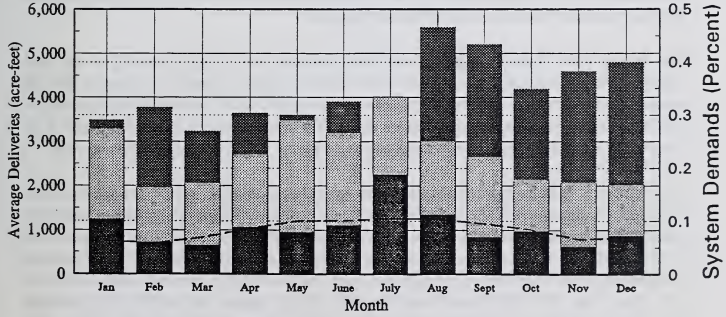
Based on Figure A-1, SFWD has normally operated Calaveras Reservoir within a range of 40,000 to 100,000 acre-feet. Calaveras Reservoir Storage fell slightly below 40,000 acre-feet in fall of 1964. Storage also was below 40,000 acre-feet during the droughts of 1976-1977 and 1987-1991. Storage also was below 40,000 acre-feet during the fall of 1974 and spring of 1975 because of construction activities on the dam. Figure 4 shows a correlation of December 1 carryover storage to annual water production. A weak correlation coefficient was derived for this comparison indicating historical variations in operational policy that are not directly related to water supply factors.

Figure 4
Calaveras Reservoir Carryover Storage
SFWD 1963-1989 Historical Operation



Excludes 1973 & 74 Construction Drawdown
Logarithmic Correlation R^2 = .55

Figure 5
Calaveras Reservoir Water Supply Releases
1963-1989 Actual



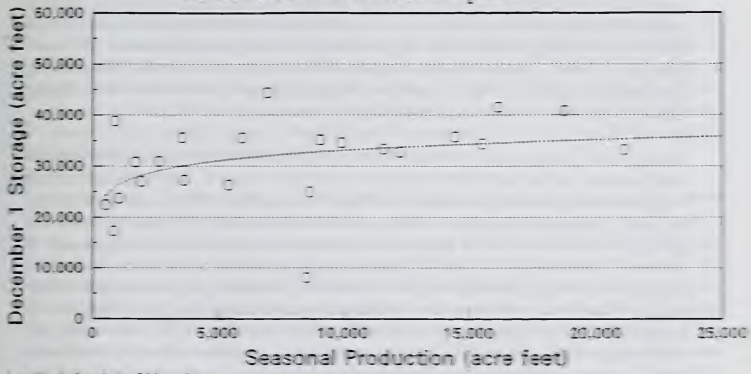
(1973 & 1974 excluded from analysis
due to drawdown for construction)

On a monthly basis, the largest quantities of water supply releases from Calaveras Reservoir occurred during the springs of 1973 and 1974, when the reservoir was being drained during some periods of relatively high inflow. Water supply during some months in 1973 and 1974 exceeded 15,000 acre-feet. Except for the unusual 1973-1974 drawdown period, water supply from Calaveras Reservoir consistently stays below 7,000 acre-feet a month. Average supply releases during the entire 1963 through 1989 study period was 36,200 acre-feet per year. Figure 5 summarizes seasonal water supply release patterns for Calaveras Reservoir. To develop this figure, the monthly water supply release data from 1963 through 1989 was ranked by annual delivery amount, and three groups were derived that contain approximately equal numbers of years. The construction drawdown years of 1973 and 1974 were excluded from this analysis because they are so untypical of normal reservoir operations. As shown in Figure 5, water supply releases during the lowest third of water supply years represent a "dependable" amount of water delivery. Water supply for the lower third generally shows mild seasonal variation with the exception of July and January, both of which have unusually high delivery amounts. The July peak results primarily from large amounts of diversions during 1981. The January peak reflects large drawdowns in 1987 during shutdown of the Hetch Hetchy Aqueduct for inspection of the Coast Range tunnel (Nougee, 1993). With the exception of those unusual months, the average seasonal pattern of water supply releases for the lower third of water supply years corresponds closely with the typical seasonal pattern of SFWD system demands. Overall, SFWD system demands vary slightly from month to month – less than many other California urban areas. The relatively small amount of monthly variation in SFWD system demands reflects the large proportion of indoor usage, which occurs year around. Usage during summer months is higher than winter months, but the contrast between summer and winter usage is less than many other water users because of the relatively small amount of landscaped area and the mild summer climate in the SFWD service area.

The middle third of water supply years have increased water supply during winter and spring months when Calaveras Reservoir inflow is normally greatest. The upper third of water supply years have minimal increases over the middle third during the spring months, but have large increases in late summer and fall months, possibly reflecting a policy of drawing down Calaveras Reservoir storage preparatory to the subsequent runoff year.

Historical San Antonio Reservoir storage and water supply release operations are shown in Appendix A, Figure A-2. As described earlier, San Antonio Reservoir operations reflect a great degree of coordination with the Hetch Hetchy Aqueduct. Not shown in Figure A-2 are Hetch Hetchy inflows to the reservoir, which can be significant. San Antonio Reservoir has generally been operated at storage levels greater than 20,000 acre-feet, with exceptions occurring in the 1976-1977 drought and the 1987-1991 droughts. In the 1987-1991 drought, San Antonio Reservoir storage was initially drawn down steeply during 1987. The subsequent partial refilling in the reservoir during 1988 and 1989 reflects Hetch Hetchy supplies as well as purchases of South Bay Aqueduct water. Figure 6, showing a

Figure 6
San Antonio Reservoir Carryover Storage
SFWD 1967-1989 Historical Operation



correlation of San Antonio Reservoir December 1 carryover storage to local water production, had an R-squared value of .16, indicating minimal correlation. Although no correlation was identified between local runoff and San Antonio carryover storage, Figure 6 indicates that the normal amount of carryover storage in San Antonio has historically been somewhere between 30,000 and 35,000 acre-feet, essentially independent of water production. The pattern of water supply releases from San Antonio Reservoir in Appendix A, Figure A-2 shows greater seasonal and annual variations than similar Calaveras Reservoir releases and consequently were not evaluated in detail.

Finally, Sunol Pumping Plant records of water production from the Sunol Filter Galleries were obtained for the years 1979-1984, which are shown in Table 3. The Pumping Plant has not produced significant quantities of water since 1984, possibly reflecting the development of gravel quarries in the Sunol Valley and a corresponding reduction in basinwide groundwater levels. Based on these records, there was a somewhat consistent amount of flow available at the Sunol Filter Galleries, averaging about 322 acre-feet per month from January 1979 through June 1981. Prior to June 1981, this water production occurred year-round. Water production from the galleries has been minimal since June 1981, and no supply has been provided from the Sunol Pumping Plant since 1984. Historically, the SVWC and SFWD constructed temporary gravel dams to increase Alameda Creek water levels in the vicinity of the Filter Galleries and to inundate higher portions of the creek bed that are underlain by perforated pipes connected to the Filter Galleries. The effect of these operations on increased water supply could not be determined from Sunol Pumping Plant data. SFWD currently does not construct the gravel dams, which are normally washed out by higher flows.

Table 3
SUNOL PUMP STATION FLOWS (SUNOL FILTER GALLERIES INFLOW)
(Acre-feet)

Month	1979	1980	1981	1982	1983	1984
January	276.66	407.88	95.29	0.00	0.00	0.00
February	378.24	0.00	306.62	0.00	1.96	0.00
March	799.87	0.00	537.98	96.26	1.53	0.00
April	618.47	0.00	365.41	0.00	0.93	0.00
May	500.69	200.55	225.35	1.75	0.00	22.21
June	443.18	436.69	138.82	0.00	0.00	0.00
July	214.41	449.02	0.00	0.00	0.00	0.00
August	207.01	387.13	0.00	0.68	1.14	0.00
September	229.80	352.81	0.00	0.83	0.00	0.00
October	480.74	281.29	0.00	0.34	0.40	0.00
November	316.06	307.44	0.00	2.73	0.37	8.94
December	650.03	73.41	0.00	1.99	0.00	133.64
Total	5,115.16	2,896.22	1,669.47	104.58	6.33	164.79

CHAPTER 4 OPERATION MODEL

A reservoir operation model was developed to quantify the water supply available to the SFWD from the Alameda Creek watershed. The reservoir operation model attempts to mimic SFWD water management through computer simulation. In reality, operation of SFWD facilities varies daily and hourly depending on available reservoir storage, variations in user demands, Hetch Hetchy supply availability and power generation requirements, and water quality considerations. Development of a model that accounts for all these factors was outside the scope of this study.

In simulating SFWD operations in the Alameda Creek watershed, two major simplifications were made to facilitate numerical analysis. First, the reservoir simulation model uses a monthly time step. A monthly time step does not allow simulation of day-to-day operations that are affected by hourly variations in capacity, demand, and other factors. However, the monthly time step is considered appropriate for identifying seasonal variations in water supply and use conditions which are the primary concern of the Alameda Creek Watershed Study. Second, the reservoir operation model incorporates only local facilities of the Alameda Creek watershed. To varying degrees, SFWD facilities in the Alameda Creek watershed are physically or operationally affected by other facilities, primarily the Hetch Hetchy Aqueduct. San Antonio Reservoir, in particular, is directly connected to the Hetch Hetchy Aqueduct and provides storage space for supplies from the Hetch Hetchy Aqueduct.

This chapter begins with a description of the algorithm used to simulate SFWD Alameda Creek operations. The configuration of the Alameda Creek model is then discussed and its characteristics are summarized numerically.

MODEL THEORY

The Alameda Creek Operation Model has been developed using a numerical network flow model. Network flow models simulate water movement through a network consisting of nodes and arcs. In such a network, nodes represent geographic points, such as a branching location along a pipeline or a convergence of two stream channels. Arcs represent the channels that flow between nodes. Maximum and minimum flow amounts are specified for each arc, allowing specification of conveyance facility capacity (maximum) or required fisheries flows (minimum). The network flow model allows the user to specify up to eight reservoir levels that are used for balancing among reservoirs and for limiting diversion amounts. The network flow model internally specifies individual arcs for each reservoir that represent user-specified reservoir storage levels. An arc is also included for carryover storage from one time step to another.

The network flow model is mathematically solved monthly to result in the least cost. The unit cost of flow in each arc is specified that can be either a positive or negative number.

These "costs" do not necessarily represent monetary costs, but can serve as a means for assigning relative operational priorities. For example, a water delivery channel could have a very low negative assigned cost which would cause the network flow model to supply as much water as possible to that channel. Conversely, the cost of spilling water from the network can be set as a very high number, making it very expensive to allow water to spill out of the system. Reservoir levels are normally specified as intermediate values that can change from month to month as a means of assigning water to storage.

The network flow model is solved using the out-of-kilter algorithm. This algorithm is a very efficient means of quantitatively solving the network flow model. The program is currently operating on a MS-DOS operating system that can be used on IBM-compatible personal computers.

MODEL DESCRIPTION

The Alameda Creek Operation Model is configured as shown in Figure 7. As described previously, the arcs in this network represent channels which convey water and the nodes represent specific locations. The discussion below describes each arc of the Alameda Creek operation model network as well as each node. For each arc, a description is provided of the physical facility or facilities that are represented. Unless otherwise stated, the network flow cost of conveying water through an arc is zero.

Arc 1

This arc represents Calaveras Reservoir releases to the Calaveras Creek channel. Both reservoir spills and planned fisheries releases are included in this channel (fishery releases are not included in all simulations).

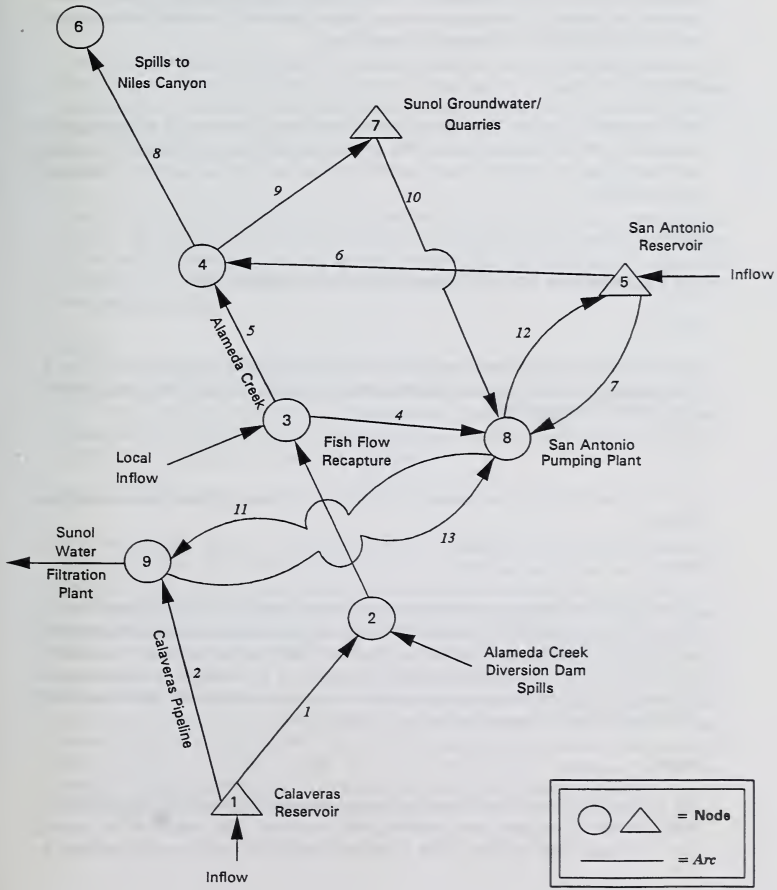
Arc 2

Water supply releases from Calaveras Reservoir to the Calaveras Pipeline are simulated with this arc. The maximum amount of releases through Arc 2 is restricted to the 170 cfs capacity of Calaveras Pipeline.

Arc 3

Flows below the confluence of Alameda and Calaveras Creeks are simulated in this arc. For simulations that include planned fisheries releases, the quantities are included in this node as required minimum flow amounts. The minimum required fishery releases can be supplied in the model either through operational spills over the Alameda Creek Diversion Dam or from Calaveras Reservoir releases.

Figure 7
ALAMEDA CREEK OPERATION MODEL



Arc 4

Fisheries flow recapture is represented in Arc 4. In simulations without planned fisheries releases, the capacity of this arc is set to zero. When operational, a nominal cost is assigned to flow through this arc to account for energy costs.

Arc 5

Arc 5 represents Alameda Creek flows between the fishery flow recovery facilities and the confluence with San Antonio Creek. This arc will normally be dry, with flows occurring only during periods of spills or local runoff (which occurs only during certain winter and spring months).

Arc 6

Arc 6 represents San Antonio Reservoir spills into San Antonio Creek.

Arc 7

San Antonio Reservoir releases through the San Antonio Pipeline are represented in Arc 7. These releases are limited by the 250 cfs capacity of the San Antonio Pumping Plant and Sunol Water Treatment Plant.

Arc 8

Arc 8 represents spills from Alameda Creek below the Sunol Water Temple into Niles Canyon.

Arc 9

This arc simulates either groundwater recharge into the Sunol Valley groundwater basin or diversions into the Sunol Valley quarry reservoirs. For groundwater recharge, the quantities are limited to the estimated capacity of the Sunol Filter Galleries. Based on historical records since 1979, the maximum monthly recovery at the Galleries was estimated as 800 acre-feet. The diversion rate into possible future quarry reservoirs will be described individually for each alternative reservoir configuration.

Arc 10

Arc 10 simulates either Sunol Pumping Station pumpage (for the current Filter Galleries configuration) or pumpage from possible quarry reservoirs. The capacity of the existing Sunol Pumping Plant is 38 cfs. The extraction capacity of future quarry reservoirs is

described later in the description of alternatives. A nominal network flow cost is assigned to this arc to account for energy consumption from pumping.

Arc 11

This arc consolidates all pumpage from the Sunol and San Antonio Pumping Plants to the Sunol Filtration Plant and is limited to the Sunol Filtration Plant capacity of 247 cfs. A cost is assigned to flow through this channel to account for the cost of energy consumption in pumping.

Arc 12

Pumpage from the San Antonio Pumping Plant into San Antonio Reservoir is simulated in this arc. The capacity of this channel is limited to about 75 cfs due to limitations imposed by the need to maintain an air gap between potable and nonpotable water. Like other pumping arcs, a cost is assigned to use of this channel to account for energy consumption required in pumping.

Arc 13

The Calaveras Pipeline connection to the San Antonio Pumping Plant is represented by Arc 13. This arc conveys direct transfers of storage from Calaveras Reservoir to San Antonio Reservoir when storage levels in San Antonio are lower than at Calaveras and is restricted by the 170 cfs capacity of the Calaveras Pipeline.

Node 1—Calaveras Reservoir

The area capacity table for Calaveras Reservoir is included in the model as shown in Table 2. Inflows to this reservoir were described previously and are shown in Appendix A, Table A5. The reservoir target levels, which control how the reservoir is operated, are shown in Figure 8. Five target levels are presented in that figure. The lowest of these represents a minimum pool level which is set at a constant 10,000 acre-feet. Only Level 1 demands (described later for Node 9) are supplied when Calaveras Reservoir falls below this level. Level 2 is also set at a constant monthly amount and is used to limit reservoir releases during extended dry year sequences. Reservoir Levels 3 and 4 represent the normal operational range of the reservoir, with Level 3 representing below-normal wetness operation and Level 4 representing above-normal wetness operation levels. The carryover target for Level 4 of 75,000 acre-feet for the end of November represents the normal carryover target for conditions of full water supply. Level 5 represents the physical capacity of Calaveras Reservoir of 100,000 acre-feet.

Figure 8
Calaveras Reservoir
Reservoir Target Levels

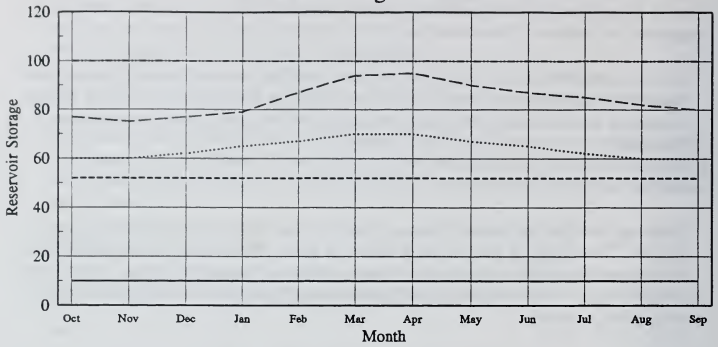
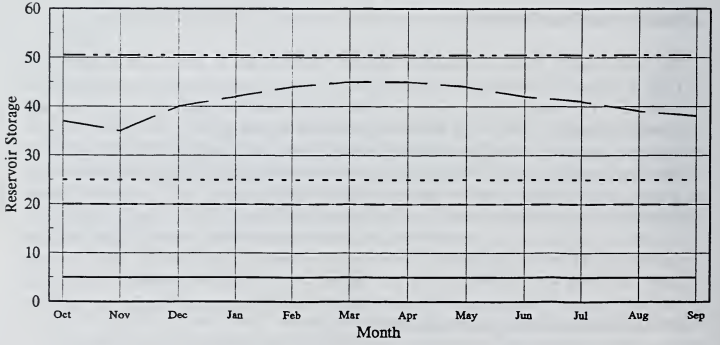


Figure 9
San Antonio Reservoir
Reservoir Target Levels



Node 2—Alameda Creek/Calaveras Creek Confluence

Inflows to this node are included in the model that represent spills from the Alameda Creek Diversion Dam.

Node 3—Fish Flow Recapture

This node represents the location of possible fishery flow recovery facilities, either surface facilities, such as dams and pumps, or subsurface facilities, such as wells.

Node 4—Alameda Creek/San Antonio Creek Confluence

This node represents the confluence of the Alameda and San Antonio Creeks. Diversions for Quarry Reservoir storage or into the Sunol Filter Galleries are also made at this location.

Node 5—San Antonio Reservoir

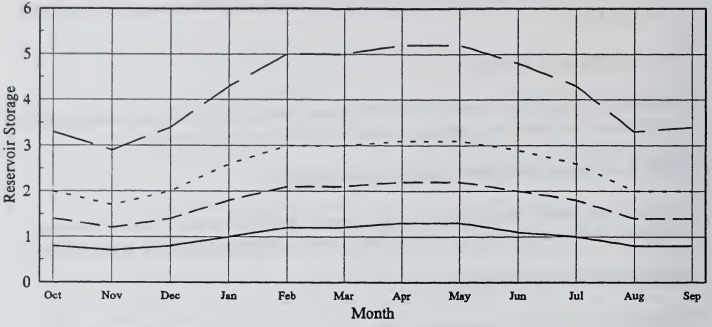
San Antonio Reservoir is represented by this node. In reality, the operation of this reservoir is coordinated closely with Hetch Hetchy Aqueduct operations. San Antonio Reservoir is one of the largest Bay Area reservoirs available to store Hetch Hetchy Aqueduct flows. By contrast, the amount of local inflow to the reservoir (averaging an estimated 7,200 acre-feet per year between 1918 and 1990) is relatively insignificant. Filling the 50,000 acre-feet reservoir would require seven years of average flows. Since the Alameda Creek Operation Model simulates only local SFWD operations, San Antonio Reservoir is used as a source of carryover storage to meet long-term demands.

Figure 9 presents the reservoir levels used to guide storage operation in San Antonio Reservoir. As with Calaveras Reservoir, these reservoir levels control the amounts of SFWD deliveries, according to the relative availability of storage. Because of the small amount of local inflow, the normal December 1 carryover storage (Level 4) for the reservoir is 40,000 acre-feet, which is only 10,000 acre-feet less than reservoir capacity. This amount of carryover provides 10,000 acre-feet of regulatory storage which is sufficient to capture the entire amount of inflow in 70 percent of the years.

Node 6—Niles Canyon

Alameda Creek flows (excluding Arroyo de la Laguna flow) that can not be controlled by SFWD are spilled in the model to Niles Canyon at this node. The Alameda Watershed Operation Model incorporates only flows from the mainstem of Alameda Creek upstream of Sunol. The total amount of spills in Niles Canyon can be estimated by adding available flows in the Arroyo de La Laguna which originate in the Livermore Valley and local watersheds.

Figure 10
Alameda Watershed
SFWD Water Demand Schedule



Level 1 (Dependable) Level 2 (Interm. Dry) Level 3 (Interm. Wet) Level 4 (As Available)

Node 7—Sunol Valley Groundwater/Quarry Reservoirs

For existing conditions, this node represents the Sunol Valley Groundwater Basin. Currently, SFWD manages the Sunol Filter Galleries and Pump Station to recapture relatively small amounts of groundwater recharge from the adjacent Alameda Creek. Minimal use of Sunol Valley groundwater occurs, and water levels are essentially full under normal conditions. Under various management alternatives, reclaimed gravel quarries in the Sunol Valley would be developed for regulatory storage. The quantities of this storage and the assumptions for operating the reservoirs are described in Chapter 5, along with the alternatives themselves.

Node 8—San Antonio Pumping Plant

The San Antonio Pumping Plant is represented by Node 8. In the model, this pumping plant allows transfer of water from San Antonio Reservoir to the Sunol Valley Filtration Plant and will also allow pumpage of recovered fishery flows for storage in San Antonio Reservoir and transfer of storage from Calaveras Reservoir to San Antonio Reservoir. In reality, although not represented in the model, the pumping plant also provides a connection to the Hetch Hetchy Aqueduct. The plant can deliver water from the Sunol Valley Filtration Plant to the Aqueduct and can also deliver water from the Aqueduct to either San Antonio Reservoir or the filtration plant.

Node 9—Sunol Valley Water Filtration Plant

Node 9 schematically represents the Sunol Valley Filtration Plant and deliveries to the Hetch Hetchy Aqueduct for meeting SFWD demands. In reality, the Filtration Plant operates in coordination with the Hetch Hetchy Aqueduct and other SFWD facilities (particularly the Peninsula reservoirs) to meet SFWD system demands. Water is treated at the Filtration Plant in response to numerous factors including requested demands, Hetch Hetchy Aqueduct supply availability, and water quality needs. Because the factors that affect production from the Sunol Valley Filtration Plant are variable, the operation of the plant is flexible and varies considerably from year to year and month to month.

To provide representative estimates of SFWD demand that allow comparable results, three levels of demands were assumed for the Alameda Creek Operation Model. Level 1 demands represent a firm level of supply that can be provided annually from the Alameda Watershed on a dependable basis. The annual total of Level 1 demands was estimated as 12,000 acre-feet, which represents the approximate amount of supply that can be produced from the Alameda Creek Watershed during the most extreme drought period of record, 1987-1992. The seasonal pattern of Level 1 demands was set to the monthly pattern of demands that SFWD historically supplied in 1987 and is summarized in Figure 9.

Level 2 and 3 demands are included in the Alameda Creek Operation Model that represent the amount of Alameda Watershed supply that can be delivered on a reasonably reliable basis, except for the most extended drought periods. The Level 2 demands are set at 21,800 acre-feet per year and Level 3 demands are set at 30,000 acre-feet per year. The level of Alameda Watershed production was defined based primarily on two factors. First, 30,000 acre-feet per year is the approximate amount of local supply that can be blended with Hetch Hetchy Aqueduct supplies to provide a desirable quality of blended water supply for SFWD users. Use of greater than 30,000 acre-feet annually of local supplies results in a less desirable blend of water quality for users such as electronics manufacturers in Palo Alto and Santa Clara. The second consideration in setting the Level 3 demands was Hetch Hetchy supply availability. In general, Alameda Creek and Tuolumne River have similar wetness variations. When runoff in Alameda Creek is sufficient to allow supply of greater than 30,000 acre-feet per year, Tuolumne River water supply conditions also typically result in surplus flow availability in the Hetch Hetchy Aqueduct. In brief, supply of greater than 30,000 acre-feet per year may result in greater use of local supplies in years of overall supply availability at the expense of maintaining overall reserves for subsequent dry years.

Also shown in Figure 9 are Level 4 demands that are supplied whenever Alameda Watershed Reservoirs are at or above their Level 4 targets. The total amount of Level 4 demands is set in the model at 50,100 acre-feet per year, which is roughly based on the historical quantities of wet year deliveries from the Alameda Watershed. Level 2, 3, and 4 demands were estimated seasonally based on SFWD's 1987 pattern of deliveries to provide water on typical use pattern. Finally, the total amount of water that could possibly be used from the Alameda Watershed is estimated with restrictions only for the capacity of the Sunol Water Filtration Plant. The amounts of this surplus water occur on an inconsistent basis with large quantities of water in a few months when total SFWD demands are low and other SFWD reservoirs would probably be spilling. This water, although physically capable of treatment, has minimal utility for SFWD operations and effectively is considered here as a form of spill. Although the quantities of these treatable spills are quantified by the Alameda Creek Operation Model, the likelihood that they would be used is probably small.

CHAPTER 5 MANAGEMENT ALTERNATIVES

The Alameda Creek Operation Model provides the capability for analyzing numerous possible water resource management alternatives. During the Alameda Creek Water Resources Study, four alternatives were identified for analysis using the model. These alternatives are summarized below:

- Alternative 1—Base Case. This alternative assumes the current configuration of facilities in the study area. This alternative further assumes that aggressive operations would be taken, such as routine reconstruction of gravel dams near the Sunol Water Temple, to maximize water recapture with the Sunol Filter Galleries.

- Alternative 2—No Sunol Facilities. This alternative assumes the current configuration of Alameda Watershed facilities, but differs from the Base Case in assuming that the Sunol Filter Galleries would not be operated.

- Alternative 3—Fish Releases. With this alternative, planned releases from Calaveras Reservoir for development of a fishery in portions of Calaveras and Alameda Creeks would be implemented as proposed in the report, *Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan*, dated November 1993. Downstream facilities would be constructed in Sunol Valley to recapture fishery releases.

- Alternative 4—Quarry Reservoirs. Under this alternative, reclamation of gravel quarries in the Sunol Valley would be planned for development of approximately 50,000 acre-feet of regulatory storage. This regulatory storage would be operated in coordination with other Alameda Watershed facilities to increase the developed water supply. In addition to quarry operation, planned releases for instream flow would occur as proposed in the November 1993 fisheries report.

The modeling assumptions made to represent each alternative in the Alameda Creek Operation Model are summarized below. The results of the alternative simulations are then described and compared with each other.

MODEL ALTERNATIVE ASSUMPTIONS

The previous chapter contains a description of the Base Case model that was used for analysis of Alternative 1. Alternative 2 is nearly identical to Alternative 1 with the exception that the Sunol Filter Galleries recovery capacity is taken to be 0 acre-feet. In Alternative 1, the Sunol Filter Galleries can recover 800 acre-feet per year, an operational recovery rate based on recent monthly records that is lower than the historical peak recovery capacity of 38 cfs.

Alternative 3 differs only slightly from Alternatives 1 and 2. With Alternative 3, the capacity of the Sunol Filter Galleries is taken to be zero. However, Alternative 3 assumes that fisheries releases would occur and that facilities would be constructed in Sunol Valley to recapture those releases. The proposed fisheries flow requires approximately 1,200 acre-feet per month in February and March for spawning and 300 acre-feet per month in November, December, and January for flow maintenance. During the remainder of the year, flows of approximately 400 acre-feet per month are required, primarily to maintain suitable temperatures for trout habitat in a portion of Calaveras and Alameda Creeks. In Alternative 3, fishery flow recapture facilities would be required to recapture the spawning fishery releases of 20 cfs (1,200 acre-feet per month). These recapture facilities could also recreate the diversion capability of the Sunol Filtration Galleries and divert unregulated local flows when capacity greater than the fishery releases is available. Four recapture facility capacities (20, 30, 50, and 100 cfs) were considered that provided varying capacities for unregulated flow diversion. Based on sensitivity analyses using the operation study, a recapture facility size of 50 cfs (6,000 acre-feet per month) was selected for this alternative.

Alternative 4 differs most from the Alternative 1 Base Case. With Alternative 4, an additional 50,000 acre-feet of reservoir storage space would be available in reclaimed Sunol Valley quarries. Available flows would be diverted into the quarry reservoirs at a maximum rate of 167 cfs and extracted with pumps sized for 83 cfs. These quarry intake and extraction rates are preliminary estimates that were selected to provide a general indication of the potential for water supply development with the quarries. Additional, detailed cost studies would be required to define the optimal size of intake and extraction facilities.

Since the quarries would be operated primarily for water supply purposes, reservoir levels were identified that operate the quarry reservoirs similar to Calaveras Reservoir. Figure 11 shows the reservoir operational levels that were assumed for the quarry reservoirs. The availability of supplemental storage in the quarries also allows respecification of reservoir levels for Calaveras and San Antonio Reservoirs, since these reservoirs would not be required to maintain the same level of carryover storage as protection from droughts. Revised lower reservoir levels were defined for Calaveras and San Antonio Reservoirs that are shown in Figures 12 and 13. This revision to reservoir levels was made to demonstrate the potential amount of additional yield.

MODEL SIMULATION RESULTS

The results of the operation model analysis of the management alternatives are summarized in Table 4. Probably the most important number shown in this figure is the estimate of average deliveries. This estimate was computed by summing the deliveries that could be provided on a regular demand pattern for Levels 1 through 4. The average amount of deliveries for the base case, which assumes continued operation of Sunol Filter

Figure 11
Quarry Reservoir
Revised Reservoir Target Levels

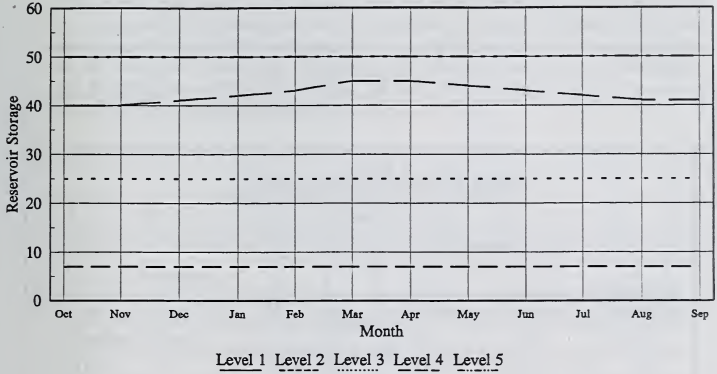


Figure 12
Calaveras Reservoir
Revised Reservoir Target Levels

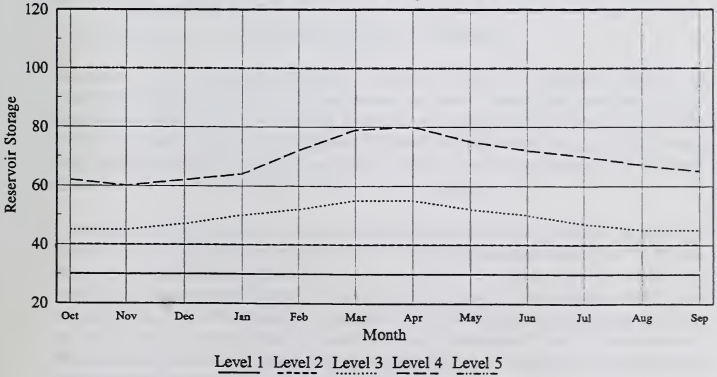
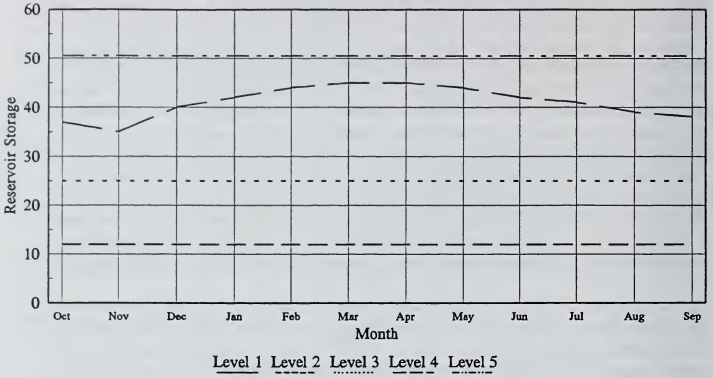


Figure 13
San Antonio Reservoir
Revised Reservoir Target Levels



Galleries, was 37,700 acre-feet per year. Loss of the Sunol Filter Galleries, as assumed in Alternative 2, results in average deliveries of about 36,500 acre-feet, a reduction of about 1,200 acre-feet per year from the base study. Implementation of planned fishery releases and the availability of fishery flow recovery facilities near the Sunol Filtration Plant result in average deliveries of 39,600 acre-feet, which is somewhat more than the average deliveries for the Alternative 1 Base Case. The closeness of the average deliveries for Alternatives 1 and 3 indicates that the proposed fishery recovery facilities provide similar operational functionality to the existing Sunol Filter Galleries.

Table 4
ALAMEDA CREEK OPERATION MODEL
1918-1990 STUDY SIMULATION RESULTS
(1,000 acre-feet)

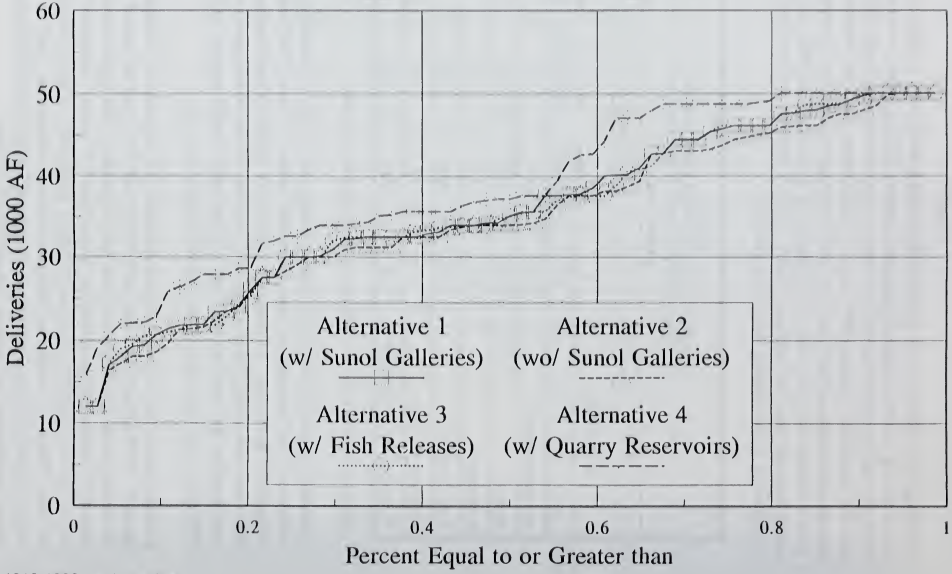
Description	Alternatives			
	1 Base Case	2 No Filter Galleries	3 With Fish Releases	4 With Quarry Reservoirs
Average Delivery	37.7	36.5	39.6	43.3
Spills	12.9	14.2	10.6	7.0
Evaporation	7.3	7.3	7.3	8.1
Total Disposal	57.9	58.0	57.5	58.4
Minimum Delivery	12	12	12	21
Probability of 15% Shortage*	0.19	0.20	0.20	0.07

*Shortage relative to Level 3 deliveries at 30,000 acre-feet per year.

Alternative 4, which incorporates Quarry Reservoirs in SFWD operations, results in an average of 43,300 acre-feet per year, an annual increase of about 5,600 acre-feet over the Alternative 1 Base Case. Alternative 4 provides an especially large increase in potential SFWD deliveries during the driest quartile of years. In the lowest quartile of years, when water supplies are most valuable and surplus Hetch Hetchy supplies are not available, Alternative 4 results in an increase of 4,000 acre-feet per year.

A comparison of the frequency of water deliveries for Alternatives 1 through 4 is shown in Figure 14. In this figure, the water deliveries for each alternative are ranked for the 73-year simulation period and are plotted from least to greatest. This figure also shows the close similarity in water deliveries between Alternatives 1, 2, and 3. Alternative 2, which does not include the Sunol Filter Galleries, is slightly lower than the other alternatives nearly all the time. There is virtually no difference between Alternatives 1 and 3. Alternative 4, which includes the quarry reservoirs, is consistently higher and results in an especially large increase in deliveries for amounts less than 30,000 acre-feet.

Figure 14
Alameda Creek Operation Model
Water Supply Delivery Frequency



1918-1990 Study Period

Alternatives 3 and 4 both provided the recommended fisheries flows in the Biosystems November 1993 report without shortage. Both Alternative 3 and 4 resulted in some months when Calaveras Reservoir storage fell slightly below the recommended minimum storage amount of 30,000 acre-feet in one or more months at the end of the study period in October 1990.

CHAPTER 6 BIBLIOGRAPHY

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APPENDIX A

Table A1

CALAVERAS CREEK NEAR SUNOL
RUNOFF
(Acre–Feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1898							910	394	1,338	44	17	15	
1899	28	11	17	8,060	1,010	23,800	5,710	1,810	1,510	762	109	37	42,864
1900	170	3,760	9,840	16,200	1,530	5,240	2,930	2,100	982	646	400	273	44,071
1901	526	18,900	1,960	15,600	13,300	4,150	1,810	3,340	1,360	707	481	265	62,399
1902	311	315	1,000	478	14,300	9,040	2,670	1,320	217	73	39	21	29,784
1903	17	970	1,660	7,130	9,660	13,000	9,100	1,190	940	569	316	118	44,670
1904	439	2,280	664	830	11,900	14,400	4,830	3,470	762	313	119	74	40,081
1905	211	227	458	2,360	6,330	11,900	4,290	4,800	762	257	76	74	31,745
1906	76	74	113	22,300	7,050	22,000	12,400	3,660	2,050	756	394	251	71,124
1907	80	270	10,300	23,100	12,200	49,100	7,910	2,820	1,310	247	76	74	107,487
1908	83	180	1,980	8,760	7,300	7,070	1,480	806	323	129	76		28,187
1909													
1910										552	365	249	
1911	265	157	266	27,600	16,600	37,300	4,150	2,240	1,070	658	492	336	91,134
1912	311	392	497	2,320	805	7,440	2,180	787	274	170	84	60	15,320
1913	52	65	151	6,640	468	904	525	257	173	118	73	51	9,477
1914	34	34	9,410	45,700	19,300	1,640	922	613	298	0	0	0	77,951
1915	0	0	2,510	13,600	39,800	3,210	3,580	10,800	1,860	436	176	155	76,127
1916	133	123	1,750	47,800	13,700	1,320	283	695	696	984	1,230	1,070	69,784
1917	652	388	516	1,290	19,800	2,090	680	996	1,390	3,980	3,570	4,560	39,912
1918	5,330	349	152	84	138	242	934	90	0	2,280	2,490	2,270	14,359
1919	3,600	898	1,340	652	7,050	16,700	2,010	1,950	2,930	3,820	3,310	3,780	48,040
1920	701	63	1,060	260	395	474	595	2,340	3,180	1,640	738	750	12,196
1921	867	881	9,590	11,600	3,140	86	1,780	1,780	1,520	1,940	2,120	2,110	37,414
1922	1,890	1,100	10,300	3,230	20,700	4,940	1,390	1,270	2,800	1,520	1,830	1,960	52,930
1923	1,670	1,390	6,030	3,240	3,000	1,510	732	1,720	2,480	3,630	3,070	3,760	32,232
1924	2,800	1,930	1,210	1,140	1,030	879	904	1,130	1,050	941	879	424	14,317
1925	134	248	156	14	7	0	1,420	1,540	3,830	2,210	1,000	1,810	12,369
1926	2,240	1,840	2,000	1,440	97	1,250	559	3,620	3,550	4,050	4,010	3,810	28,466
1927	3,830	3,210	3,300	2,210	180	280	1,330	5,770	5,780	5,180	3,730	3,690	38,490
1928	3,820	3,680	2,500	781	604	713	1,060	5,420	3,330	3,740	3,760	3,750	33,158
1929	3,850	2,460	2,090	1,730	1,230	1,350	1,590	3,540	0	163	1,250	95	19,348
1930	403	433	1,600	1,140	1,220	181	3,430	1,830	2,490				

SOURCE: U.S. Geological Survey Water Supply Paper 1315–B, based on Spring Valley Water Company records.

Table A2

ALAMEDA CREEK NEAR SUNOL
RUNOFF
(Acre--Feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1911									206	176	158	36	
1912	18	25	43	1,060	240	2,310	470	261	175	129	78	29	4,838
1913	22	21	26	2,470	209	480	293	120	85	23	12	7	3,768
1914	0	8	3,440	12,500	6,000	695	263	154	92	0	0	0	23,152
1915	0	0	511	5,590	13,800	2,010	1,060	4,460	519	155	62	55	28,222
1916	47	43	719	18,900	7,130	2,330	550	218	76	59	22	12	30,106
1917	0	0	2,470	1,960	9,330	2,180	672	421	220	0	0	0	17,253
1918	0	0	0	0	633	2,600	296	87	41	0	0	244	3,901
1919	14	317	350	369	9,610	6,330	660	209	64	0	0	0	17,923
1920	0	0	255	51	46	2,930	2,070	121	10	0	0	0	5,483
1921	0	226	3,860	5,450	2,900	799	343	221	66	0	0	0	13,865
1922	0	0	2,310	1,410	11,900	5,530	1,930	536	124	0	0	0	23,740
1923	0	242	5,740	3,040	2,570	530	1,680	238	0	0	0	0	14,040
1924	0	0	0	0	0	3	11	0	0	0	0	0	14
1925	0	0	483	456	4,240	291	631	652	0	0	0	0	6,753
1926	0	0	0	472	8,390	633	2,360	165	0	0	0	0	12,020
1927	0	1,890	627	1,640	7,780	2,120	2,672	322	4	0	0	0	17,055
1928	0	0	1,210	621	1,160	7,440	2,840	287	11	0	0	0	13,569
1929	0	0	1,090	842	850	1,220	514	144	67	0	0	0	4,727
1930	0	0	0	1,110	1,110	4,570	372	172	39	0	0	0	7,373

SOURCE: U.S. Geological Survey Water Supply Paper 1315-B, based on Spring Valley Water Company records.

Table A3

SAN ANTONIO (LA COSTA) CREEK NEAR SUNOL
RUNOFF
(Acre--Feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1912				341	129	565	168	98	28	8	0	0	
1913	0	10	49	959	125	237	243	133	10	9	0	0	1,775
1914	0	7	1,660	9,280	3,900	1,300	672	363	151	0	0	0	17,333
1915	0	0	209	2,600	11,400	1,760	660	2,630	305	57	29	24	19,674
1916	22	20	855	15,900	5,650	2,830	486	239	120	26	11	10	26,169
1917	23	22	738	738	3,380	1,410	323	152	42	0	0	0	6,828
1918	0	2	12	18	212	1,760	115	38	0	0	0	169	2,326
1919	9	221	90	267	5,890	4,570	557	285	33	0	0	0	11,922
1920	0	0	41	58	166	1,830	803	90	0	0	0	0	2,988
1921	0	0	1,540	3,840	2,080	726	407	322	88	0	0	0	9,003
1922	0	0	1,210	996	7,110	2,840	887	184	41	2	0	0	13,270
1923	0	76	2,320	1,740	1,160	283	450	63	3	0	0	0	6,095
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	143	122	2,350	314	471	133	24	0	0	0	3,557
1926	0	0	0	7	3,530	231	1,050	26	0	0	0	0	4,844
1927	0	304	331	79	3,380	1,090	1,130	360	151	0	0	0	6,825
1928	0	0	379	538	788	3,340	1,460	67	25	9	0	0	6,606
1929	0	20	157	147	275	473	58	14	3	0	0	0	1,147
1930	0	0	70	695	434	2,590	233	148	96	0	0	0	4,266

SOURCE: U.S. Geological Survey Water Supply Paper 1315-B, based on Spring Valley Water Company records.

Table A4

ARROYO HONDO NEAR SAN JOSE
RUNOFF
(Acre–Feet)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1969	39	194	2,064	23,658	26,745	9,368	2,995	990	465	167	80	76	66,841
1970	125	166	841	14,686	3,255	8,777	1,075	554	233	87	62	49	29,910
1971	55	1,383	10,604	5,282	940	3,532	1,509	681	284	94	44	34	24,442
1972	57	98	2,779	969	1,819	399	284	133	81	32	11	16	6,678
1973	39	4,130	2,079	15,374	26,836	12,742	2,404	900	364	153	82	77	65,180
1974	229	2,567	11,209	10,844	1,706	10,481	10,602	1,480	566	295	108	46	50,133
1975	141	250	771	1,553	18,829	20,830	5,823	1,460	506	268	163	132	50,726
1976	171	203	230	206	235	576	235	102	44	26	22	26	2,076
1977	75	80	87	388	165	343	175	124	48	20	13	15	1,533
1978	15	40	981	18,048	10,352	12,883	5,224	1,234	475	167	85	78	49,582
1979	75	135	201	3,531	9,483	5,094	1,660	588	174	82	43	37	21,103
1980	94	283	2,391	15,953	30,647	6,518	2,450	972	399	190	95	57	60,049
1981	68	91	279	7,913	1,539	7,095	1,333	489	168	41	23	21	19,060

Table A5
Inflow to Calaveras Reservoir (excluding Alameda Creek diversion)

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1918	17.	46.	101.	101.	1610.	6642.	754.	222.	102.	43.	29.	626.	10293.
1919	217.	811.	890.	943.	24518.	16183.	1682.	530.	163.	133.	74.	52.	46196.
1920	79.	84.	654.	132.	121.	7582.	5363.	315.	25.	54.	34.	27.	14470.
1921	41.	598.	10089.	14285.	7616.	2099.	899.	577.	173.	110.	62.	45.	36594.
1922	64.	68.	5740.	3507.	29497.	13741.	4809.	1334.	308.	166.	90.	62.	59386.
1923	97.	628.	14895.	7894.	6687.	1388.	4354.	618.	296.	110.	62.	45.	37074.
1924	5.	0.	0.	0.	0.	2.	11.	0.	0.	0.	0.	0.	18.
1925	18.	47.	1247.	1175.	10945.	754.	1632.	1692.	184.	62.	38.	29.	17823.
1926	44.	47.	102.	1215.	21696.	1637.	6094.	429.	269.	96.	55.	40.	31724.
1927	61.	4918.	1615.	4256.	20234.	5521.	6972.	840.	337.	130.	72.	51.	45007.
1928	77.	82.	3167.	1614.	3036.	19413.	7435.	747.	29.	108.	61.	44.	35813.
1929	65.	70.	2835.	2173.	2202.	3150.	1328.	372.	173.	49.	32.	25.	12474.
1930	38.	47.	103.	2872.	2872.	11877.	967.	447.	99.	66.	41.	31.	19460.
1931	70.	74.	175.	1214.	518.	627.	209.	155.	84.	39.	31.	27.	3223.
1932	26.	45.	9762.	5224.	9419.	1170.	824.	407.	239.	82.	48.	36.	27282.
1933	79.	84.	146.	2775.	947.	1367.	935.	625.	130.	51.	36.	30.	7205.
1934	33.	49.	3246.	4381.	4464.	1465.	441.	215.	162.	56.	36.	28.	14576.
1935	49.	184.	373.	10786.	994.	3965.	8955.	1825.	306.	106.	62.	46.	27651.
1936	67.	89.	386.	2672.	18033.	2956.	2981.	1101.	307.	107.	62.	46.	28807.
1937	67.	71.	277.	1200.	13995.	18790.	5641.	1539.	374.	143.	80.	57.	42234.
1938	68.	128.	6032.	6477.	36996.	24808.	6766.	1869.	530.	231.	122.	83.	84110.
1939	218.	410.	1703.	1199.	2584.	2242.	718.	307.	185.	69.	47.	38.	9720.
1940	34.	46.	101.	10867.	26414.	16209.	7883.	1542.	442.	184.	99.	68.	63889.
1941	98.	158.	5635.	12326.	27492.	20393.	25505.	4576.	611.	272.	142.	96.	97304.
1942	153.	337.	6933.	20202.	18192.	7244.	10871.	3799.	479.	202.	108.	74.	68594.
1943	128.	1236.	1160.	22021.	8177.	9371.	3210.	1439.	403.	158.	87.	61.	47451.
1944	107.	242.	475.	903.	7103.	5768.	1550.	900.	243.	82.	51.	39.	17463.
1945	54.	344.	785.	1909.	16334.	4913.	2010.	1534.	316.	110.	64.	47.	28420.
1946	65.	449.	14745.	7590.	3640.	2207.	1810.	1133.	310.	112.	64.	47.	32172.
1947	116.	782.	1079.	1104.	1962.	2733.	1834.	707.	231.	84.	56.	45.	10733.
1948	63.	132.	400.	384.	536.	1949.	3249.	1476.	180.	68.	47.	39.	8523.
1949	45.	64.	529.	574.	1488.	16524.	1875.	1307.	306.	101.	61.	45.	22919.
1950	54.	57.	312.	5813.	6406.	1524.	1222.	609.	183.	62.	39.	30.	16311.
1951	47.	7422.	18216.	8424.	7020.	8414.	1738.	1444.	426.	172.	94.	65.	53482.
1952	83.	217.	8459.	34463.	13576.	20646.	5052.	1605.	541.	236.	125.	84.	85087.
1953	152.	218.	9813.	14381.	3126.	4081.	1583.	1587.	324.	119.	68.	49.	35501.
1954	87.	534.	316.	3415.	6133.	5186.	2143.	889.	264.	88.	54.	41.	19150.
1955	58.	199.	3596.	5550.	1681.	1797.	1295.	893.	208.	71.	45.	35.	15428.
1956	38.	85.	35572.	22787.	16423.	6189.	2241.	1211.	527.	230.	121.	82.	85506.
1957	189.	202.	309.	966.	7557.	2008.	1329.	1882.	221.	76.	48.	38.	14825.

Table A5 (Continued)
Inflow to Calaveras Reservoir (excluding Alameda Creek diversion)

(ACRE FEET)

ER AR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
8	39.	176.	1078.	5655.	27075.	23883.	35242.	3758.	626.	279.	146.	98.	98055.
9	161.	172.	352.	3595.	10427.	1564.	844.	494.	195.	65.	40.	31.	17940.
0	51.	54.	138.	1024.	5593.	654.	503.	395.	118.	45.	31.	25.	8631.
1	55.	326.	294.	692.	533.	1609.	365.	274.	109.	47.	36.	31.	4371.
2	31.	52.	265.	320.	14794.	5960.	1216.	939.	254.	85.	50.	38.	24004.
3	58.	138.	939.	15597.	22391.	6323.	12632.	5895.	515.	216.	116.	80.	64900.
4	137.	1529.	747.	5409.	927.	1047.	812.	537.	167.	60.	40.	32.	11444.
5	37.	418.	16034.	28836.	4756.	1666.	9683.	1614.	448.	187.	100.	69.	63848.
6	119.	1588.	3849.	3273.	4391.	1621.	315.	357.	191.	65.	41.	32.	15842.
7	43.	356.	4982.	18276.	7261.	14793.	14662.	6201.	484.	204.	109.	75.	67446.
8	131.	196.	759.	7497.	4013.	3199.	1580.	890.	231.	77.	47.	36.	18656.
9	46.	229.	2436.	27916.	31559.	11054.	3534.	1168.	549.	197.	94.	90.	78872.
0	148.	196.	992.	17329.	3841.	10357.	1269.	654.	275.	103.	73.	58.	35295.
1	65.	1632.	12513.	6233.	1109.	3106.	1781.	804.	335.	111.	52.	40.	27781.
2	67.	116.	3279.	1143.	2146.	471.	335.	157.	96.	38.	13.	19.	7880.
3	46.	4873.	2453.	18141.	31666.	15036.	2837.	1062.	430.	181.	97.	91.	76913.
4	270.	3029.	13227.	12796.	2013.	12368.	12510.	1746.	668.	348.	127.	54.	59156.
5	166.	295.	910.	1833.	22218.	24579.	6871.	1723.	597.	316.	192.	156.	59856.
6	202.	240.	271.	243.	277.	680.	277.	120.	52.	31.	26.	31.	2450.
7	89.	94.	103.	458.	195.	405.	207.	146.	57.	24.	15.	18.	1811.
8	18.	47.	1158.	21297.	12215.	15202.	6164.	1456.	561.	197.	100.	92.	58507.
9	89.	159.	237.	4167.	11190.	6011.	1959.	694.	205.	97.	51.	44.	24903.
0	111.	334.	2821.	18825.	36163.	7691.	2891.	1147.	471.	224.	112.	67.	70857.
1	80.	107.	329.	9337.	1816.	8372.	1573.	577.	198.	48.	27.	25.	22489.
2	38.	2165.	4509.	22525.	13609.	10056.	31526.	4260.	584.	257.	135.	91.	89755.
3	127.	1947.	9143.	29103.	34857.	53571.	12367.	8231.	875.	407.	209.	138.	150975.
4	286.	4273.	18541.	2912.	1632.	1810.	1593.	1366.	342.	123.	71.	51.	33000.
5	99.	2824.	1426.	700.	2948.	3524.	515.	528.	227.	80.	52.	41.	12964.
6	37.	167.	460.	437.	41431.	23395.	4013.	1321.	486.	207.	110.	46.	72110.
7	72.	78.	243.	425.	1330.	1176.	394.	130.	84.	34.	25.	21.	4012.
8	32.	80.	880.	1692.	385.	279.	345.	156.	84.	34.	25.	21.	4013.
9	33.	51.	379.	418.	371.	1407.	377.	111.	79.	33.	25.	21.	3305.
0	30.	374.	297.	946.	1116.	639.	317.	237.	91.	36.	26.	21.	4130.
TAL	6084.	49619.	278017.	538824.	748492.	558043.	317679.	93847.	21374.	8894.	4960.	4236.	2630069.
EAN	83.	680.	3808.	7381.	10253.	7644.	4352.	1286.	293.	122.	68.	58.	36028.

Table A6
Total Runoff at Alameda Creek Diversion Dam

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1918	1.	4.	34.	34.	540.	2229.	253.	75.	34.	3.	2.	210.	3419.
1919	72.	275.	301.	320.	8309.	5484.	570.	180.	55.	10.	6.	4.	15586.
1920	6.	6.	220.	44.	41.	2557.	1808.	106.	8.	4.	3.	2.	4805.
1921	3.	200.	3370.	4771.	2544.	701.	300.	193.	58.	9.	5.	3.	12157.
1922	5.	5.	1918.	1172.	9857.	4592.	1607.	446.	103.	12.	7.	5.	19729.
1923	8.	211.	5012.	2656.	2250.	467.	1465.	208.	23.	9.	5.	3.	12317.
1924	2.	0.	0.	0.	0.	2.	9.	0.	0.	0.	0.	0.	13.
1925	1.	4.	421.	397.	3696.	255.	551.	571.	14.	5.	3.	2.	5920.
1926	3.	4.	8.	410.	7324.	552.	2057.	145.	21.	7.	4.	3.	10538.
1927	4.	1503.	494.	1300.	6183.	1687.	2130.	257.	24.	9.	5.	4.	13600.
1928	6.	6.	1061.	540.	1017.	6501.	2490.	250.	10.	8.	5.	3.	11897.
1929	5.	5.	956.	733.	743.	1062.	448.	125.	58.	4.	2.	2.	4143.
1930	3.	4.	35.	962.	962.	3980.	324.	150.	33.	5.	3.	2.	6463.
1931	6.	6.	62.	428.	183.	221.	74.	55.	30.	3.	2.	2.	1072.
1932	2.	3.	3265.	1747.	3150.	391.	276.	136.	80.	6.	4.	3.	9063.
1933	6.	7.	50.	950.	324.	468.	320.	214.	44.	4.	3.	2.	2392.
1934	3.	4.	1090.	1471.	1499.	492.	148.	72.	54.	4.	3.	2.	4842.
1935	4.	14.	125.	3628.	334.	1334.	3013.	614.	103.	8.	5.	3.	9185.
1936	5.	7.	130.	897.	6051.	992.	1000.	369.	103.	8.	5.	4.	9571.
1937	5.	5.	93.	402.	4685.	6290.	1888.	515.	125.	11.	6.	4.	14029.
1938	5.	10.	2016.	2164.	12362.	8289.	2261.	625.	177.	18.	9.	6.	27942.
1939	18.	33.	603.	425.	915.	794.	254.	109.	66.	6.	4.	3.	3230.
1940	3.	4.	34.	3629.	8821.	5413.	2632.	515.	148.	14.	8.	5.	21226.
1941	7.	12.	1884.	4120.	9189.	6816.	8525.	1530.	204.	21.	11.	7.	32326.
1942	12.	26.	2326.	6778.	6103.	2431.	3647.	1274.	161.	15.	8.	6.	22787.
1943	10.	96.	396.	7520.	2792.	3200.	1096.	491.	138.	12.	7.	5.	15763.
1944	8.	19.	162.	307.	2415.	1961.	527.	306.	83.	6.	4.	3.	5801.
1945	4.	26.	265.	645.	5519.	1660.	679.	518.	107.	8.	5.	4.	9440.
1946	5.	35.	4986.	2567.	1231.	747.	612.	383.	105.	9.	5.	4.	10689.
1947	10.	64.	389.	398.	707.	985.	661.	255.	83.	7.	5.	4.	3568.
1948	5.	10.	137.	132.	184.	669.	1115.	506.	62.	5.	4.	3.	2832.
1949	3.	5.	178.	193.	500.	5548.	630.	439.	103.	8.	5.	3.	7615.
1950	4.	4.	105.	1954.	2153.	512.	411.	205.	62.	5.	3.	2.	5420.
1951	4.	633.	6819.	3154.	2628.	3150.	651.	541.	160.	15.	8.	6.	17769.
1952	6.	17.	2829.	11527.	4541.	6905.	1690.	537.	181.	18.	9.	6.	28266.
1953	12.	17.	3303.	4841.	1052.	1374.	533.	534.	109.	9.	5.	4.	11793.
1954	7.	42.	109.	1173.	2106.	1781.	736.	305.	91.	7.	4.	3.	6364.
1955	4.	15.	1219.	1882.	570.	610.	439.	303.	70.	5.	3.	3.	5123.
1956	3.	6.	11877.	7608.	5483.	2066.	748.	404.	176.	18.	9.	6.	28404.
1957	15.	16.	106.	331.	2585.	687.	454.	644.	76.	6.	4.	3.	4927.

Table A6 (Continued)
Total Runoff at Alameda Creek Diversion Dam

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1958	3.	13.	360.	1890.	9047.	7980.	11776.	1256.	209.	21.	11.	7.	32573.
1959	12.	13.	119.	1219.	3535.	530.	286.	168.	66.	5.	3.	2.	5958.
1960	4.	4.	47.	347.	1893.	221.	170.	134.	40.	3.	2.	2.	2867.
1961	5.	27.	107.	252.	194.	586.	133.	100.	40.	4.	3.	3.	1454.
1962	2.	4.	89.	107.	4955.	1996.	407.	315.	85.	6.	4.	3.	7973.
1963	149.	10.	312.	5184.	7442.	2102.	4199.	1959.	171.	16.	9.	6.	21559.
1964	12.	132.	283.	2045.	350.	396.	307.	203.	63.	5.	3.	3.	3802.
1965	3.	32.	5379.	9674.	1596.	559.	3249.	542.	150.	14.	8.	5.	21211.
1966	10.	132.	1405.	1195.	1603.	592.	115.	130.	70.	5.	3.	3.	5263.
1967	3.	27.	1670.	6127.	2434.	4959.	4915.	2079.	162.	16.	8.	6.	22406.
1968	10.	15.	257.	2542.	1361.	1085.	536.	302.	78.	6.	4.	3.	6199.
1969	4.	17.	814.	9334.	10552.	3696.	1182.	391.	183.	15.	7.	7.	26202.
1970	11.	15.	334.	5831.	1292.	3485.	427.	220.	93.	8.	6.	4.	11726.
1971	5.	130.	4389.	2186.	389.	1089.	625.	282.	118.	9.	4.	3.	9229.
1972	5.	9.	1117.	389.	731.	160.	114.	53.	33.	3.	1.	1.	2616.
1973	4.	390.	861.	6364.	11109.	5275.	995.	373.	151.	14.	8.	7.	25551.
1974	22.	241.	4625.	4474.	704.	4325.	4375.	611.	234.	28.	10.	4.	19653.
1975	13.	23.	307.	618.	7490.	8286.	2316.	581.	201.	24.	15.	12.	19886.
1976	18.	22.	108.	97.	111.	271.	111.	48.	21.	3.	2.	3.	815.
1977	7.	8.	38.	169.	72.	150.	76.	54.	21.	2.	1.	1.	599.
1978	1.	4.	387.	7117.	4082.	5081.	2060.	487.	187.	15.	8.	7.	19436.
1979	7.	12.	80.	1403.	3769.	2024.	660.	234.	69.	7.	4.	3.	8272.
1980	8.	26.	946.	6312.	12126.	2579.	969.	385.	158.	17.	9.	5.	23540.
1981	6.	8.	110.	3133.	609.	2809.	528.	194.	67.	4.	2.	2.	7472.
1982	3.	168.	1533.	7660.	4628.	3420.	10721.	1449.	199.	20.	10.	7.	29818.
1983	10.	150.	3082.	9810.	11750.	18058.	4169.	2775.	295.	31.	16.	11.	50157.
1984	24.	364.	6939.	1090.	611.	678.	596.	511.	128.	11.	6.	4.	10962.
1985	9.	262.	581.	285.	1201.	1435.	210.	215.	92.	7.	5.	4.	4306.
1986	3.	13.	154.	146.	13847.	7819.	1341.	441.	162.	16.	8.	3.	23953.
1987	6.	6.	84.	148.	462.	409.	137.	45.	29.	3.	2.	2.	1333.
1988	2.	6.	303.	584.	133.	96.	119.	54.	29.	3.	2.	2.	1333.
1989	3.	4.	131.	144.	128.	486.	130.	38.	27.	3.	2.	2.	1098.
1990	3.	31.	108.	346.	408.	234.	116.	87.	33.	3.	2.	2.	1373.
EAR TOTAL	682.	5681.	95447.	182432.	252162.	188726.	107102.	31821.	7006.	688.	386.	488.	872621.
YEAR MEAN	9.	78.	1307.	2499.	3454.	2585.	1467.	436.	96.	9.	5.	7.	11954.

Table A7
Inflow to San Antonio

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1918	0.	2.	12.	18.	210.	1728.	113.	37.	0.	0.	0.	166.	2286.
1919	9.	217.	87.	261.	5752.	4484.	546.	278.	32.	0.	0.	0.	11666.
1920	0.	0.	39.	57.	163.	1789.	792.	88.	0.	0.	0.	0.	2928.
1921	0.	0.	1512.	3771.	2043.	714.	400.	316.	86.	0.	0.	0.	8842.
1922	0.	0.	1182.	973.	6980.	2785.	871.	181.	40.	2.	0.	0.	13014.
1923	0.	76.	2273.	1707.	1136.	277.	443.	62.	3.	0.	0.	0.	5977.
1924	0.	0.	0.	0.	0.	1.	3.	0.	0.	0.	0.	0.	4.
1925	0.	0.	140.	121.	2307.	307.	459.	131.	25.	0.	0.	0.	3490.
1926	0.	0.	0.	7.	3459.	224.	1029.	25.	0.	0.	0.	0.	4744.
1927	0.	298.	326.	784.	3311.	1080.	1099.	353.	148.	0.	0.	0.	7399.
1928	0.	0.	371.	525.	775.	3279.	1424.	84.	26.	12.	0.	0.	6496.
1929	0.	20.	153.	144.	270.	464.	58.	14.	3.	0.	0.	0.	1126.
1930	0.	0.	68.	679.	425.	2536.	228.	145.	94.	0.	0.	0.	4175.
1931	0.	0.	27.	185.	79.	159.	53.	40.	0.	0.	0.	0.	543.
1932	0.	0.	1991.	991.	1915.	297.	209.	103.	31.	2.	0.	0.	5539.
1933	0.	0.	22.	451.	144.	348.	238.	159.	7.	0.	0.	0.	1369.
1934	0.	0.	555.	805.	824.	373.	112.	55.	14.	0.	0.	0.	2738.
1935	0.	19.	57.	2217.	152.	938.	1982.	464.	45.	7.	0.	0.	5881.
1936	0.	0.	59.	429.	3572.	727.	732.	280.	45.	8.	0.	0.	5852.
1937	0.	0.	42.	183.	2894.	4041.	1289.	391.	59.	15.	2.	0.	8916.
1938	0.	7.	1169.	1267.	6754.	5301.	1524.	475.	92.	34.	11.	3.	16637.
1939	5.	67.	260.	183.	409.	570.	183.	78.	19.	0.	0.	0.	1774.
1940	0.	0.	15.	2234.	4978.	3501.	1758.	392.	74.	24.	6.	0.	12982.
1941	2.	13.	1082.	2556.	5159.	4377.	5447.	1066.	110.	43.	15.	5.	19875.
1942	5.	51.	1368.	3936.	3598.	1624.	2384.	903.	81.	28.	8.	1.	13987.
1943	5.	242.	177.	4241.	1642.	2069.	780.	366.	65.	18.	3.	0.	9608.
1944	3.	31.	73.	138.	1405.	1315.	394.	229.	31.	2.	0.	0.	3621.
1945	0.	53.	120.	291.	3287.	1136.	511.	390.	47.	8.	0.	0.	5843.
1946	0.	75.	3020.	1512.	642.	561.	460.	288.	46.	9.	0.	0.	6613.
1947	5.	146.	165.	168.	299.	680.	466.	180.	29.	3.	0.	0.	2141.
1948	0.	8.	61.	59.	82.	496.	788.	375.	18.	0.	0.	0.	1887.
1949	0.	0.	81.	88.	227.	3567.	477.	332.	45.	6.	0.	0.	4823.
1950	0.	0.	48.	1121.	1252.	388.	311.	155.	19.	0.	0.	0.	3294.
1951	0.	1553.	3603.	1696.	1387.	1869.	442.	367.	70.	21.	5.	0.	11013.
1952	0.	26.	1704.	6329.	2824.	4430.	1165.	408.	95.	35.	11.	3.	17030.
1953	5.	26.	2002.	2959.	529.	962.	402.	403.	49.	10.	0.	0.	7347.
1954	0.	93.	48.	593.	1191.	1194.	545.	226.	36.	4.	0.	0.	3930.
1955	0.	22.	632.	1063.	256.	457.	329.	227.	24.	0.	0.	0.	3010.
1956	0.	0.	6515.	4370.	3302.	1404.	570.	308.	92.	34.	11.	2.	16608.
1957	5.	23.	47.	147.	1505.	511.	338.	479.	27.	1.	0.	0.	3083.

Table A7 (Continued)
Inflow to San Antonio

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1958	0.	17.	164.	1086.	5089.	5107.	7485.	895.	113.	44.	16.	6.	20022.
1959	5.	16.	54.	632.	2138.	398.	214.	126.	21.	0.	0.	0.	3604.
1960	0.	0.	21.	156.	1072.	166.	128.	100.	5.	0.	0.	0.	1648.
1961	0.	49.	45.	106.	81.	409.	93.	70.	3.	0.	0.	0.	856.
1962	0.	0.	40.	49.	3028.	1356.	309.	239.	34.	3.	0.	0.	5058.
1963	200.	9.	143.	3163.	4303.	1432.	2752.	1342.	89.	31.	10.	2.	13476.
1964	19.	304.	114.	1032.	141.	266.	206.	137.	15.	0.	0.	0.	2234.
1965	0.	68.	3236.	5385.	888.	424.	2135.	410.	75.	25.	6.	0.	12652.
1966	5.	317.	688.	561.	808.	412.	80.	91.	21.	0.	0.	0.	2983.
1967	0.	55.	938.	3613.	1440.	3205.	3177.	1406.	83.	28.	8.	1.	13954.
1968	7.	21.	116.	1492.	724.	778.	402.	226.	29.	1.	0.	0.	3796.
1969	0.	29.	377.	5230.	5842.	2422.	848.	297.	96.	27.	5.	4.	15177.
1970	10.	22.	151.	3454.	686.	2276.	323.	166.	38.	7.	1.	0.	7134.
1971	0.	326.	2597.	1213.	169.	758.	453.	204.	51.	9.	0.	0.	5780.
1972	0.	5.	563.	174.	327.	120.	85.	40.	0.	0.	0.	0.	1314.
1973	0.	1013.	381.	3590.	5860.	3255.	702.	270.	71.	23.	6.	4.	15175.
1974	31.	622.	2754.	2659.	307.	2697.	2727.	444.	122.	59.	12.	0.	12434.
1975	13.	43.	139.	280.	4274.	5253.	1546.	438.	107.	52.	26.	18.	12189.
1976	19.	31.	41.	37.	42.	173.	71.	31.	0.	0.	0.	0.	445.
1977	0.	0.	16.	70.	30.	103.	53.	37.	0.	0.	0.	0.	309.
1978	0.	0.	177.	4120.	2532.	3290.	1398.	370.	99.	27.	6.	5.	12024.
1979	0.	14.	36.	758.	2306.	1366.	498.	176.	24.	6.	0.	0.	5184.
1980	4.	51.	462.	3705.	6614.	1718.	713.	292.	80.	33.	9.	0.	13681.
1981	0.	3.	50.	1897.	277.	1860.	400.	147.	22.	0.	0.	0.	4656.
1982	0.	439.	833.	4326.	2829.	2213.	6707.	1000.	104.	39.	14.	4.	18508.
1983	7.	392.	1855.	5429.	6395.	11322.	2697.	1831.	165.	71.	29.	14.	30207.
1984	34.	885.	3657.	482.	249.	460.	405.	347.	52.	11.	0.	0.	6582.
1985	2.	578.	217.	107.	490.	846.	131.	134.	28.	2.	0.	0.	2535.
1986	0.	15.	70.	67.	7498.	5005.	948.	336.	83.	29.	8.	0.	14059.
1987	0.	0.	37.	65.	203.	299.	100.	33.	0.	0.	0.	0.	737.
1988	0.	0.	134.	258.	59.	71.	88.	40.	0.	0.	0.	0.	650.
1989	0.	0.	58.	64.	57.	358.	96.	28.	0.	0.	0.	0.	661.
1990	0.	59.	45.	144.	170.	163.	81.	60.	0.	0.	0.	0.	722.
EAR TOTAL	400.	8451.	51315.	104663.	144067.	122944.	69405.	22616.	3357.	853.	228.	238.	528537.
YEAR MEAN	5.	116.	703.	1434.	1974.	1684.	951.	310.	46.	12.	3.	3.	7240.

Table A8
Sunol Valley Local Inflow
Portion of Basin below San Antonio, Calaveras and Alameda Creek Dams
Excluding Sinbad and Vallecitos Creeks

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1918	0.	0.	3.	4.	50.	415.	27.	9.	0.	0.	0.	40.	548.
1919	2.	52.	21.	63.	1380.	1076.	131.	67.	8.	0.	0.	0.	2800.
1920	0.	0.	9.	14.	39.	429.	190.	21.	0.	0.	0.	0.	702.
1921	0.	0.	363.	905.	490.	171.	96.	76.	21.	0.	0.	0.	2122.
1922	0.	0.	284.	234.	1675.	668.	209.	43.	10.	0.	0.	0.	3123.
1923	0.	18.	546.	410.	273.	66.	106.	15.	1.	0.	0.	0.	1435.
1924	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.	1.
1925	0.	0.	34.	29.	554.	74.	110.	31.	6.	0.	0.	0.	838.
1926	0.	0.	0.	2.	830.	54.	247.	6.	0.	0.	0.	0.	1139.
1927	0.	72.	78.	188.	795.	259.	264.	85.	36.	0.	0.	0.	1777.
1928	0.	0.	89.	126.	186.	787.	342.	20.	6.	3.	0.	0.	1559.
1929	0.	5.	37.	35.	65.	111.	14.	3.	1.	0.	0.	0.	271.
1930	0.	0.	16.	163.	102.	609.	55.	35.	23.	0.	0.	0.	1003.
1931	0.	0.	6.	44.	19.	38.	13.	10.	0.	0.	0.	0.	130.
1932	0.	0.	478.	238.	460.	71.	50.	25.	7.	0.	0.	0.	1329.
1933	0.	0.	5.	108.	35.	84.	57.	38.	2.	0.	0.	0.	329.
1934	0.	0.	133.	193.	198.	90.	27.	13.	3.	0.	0.	0.	657.
1935	0.	5.	14.	532.	36.	225.	476.	111.	11.	2.	0.	0.	1412.
1936	0.	0.	14.	103.	857.	174.	176.	67.	11.	2.	0.	0.	1404.
1937	0.	0.	10.	44.	695.	970.	309.	94.	14.	4.	0.	0.	2140.
1938	0.	2.	281.	304.	1621.	1272.	366.	114.	22.	8.	3.	1.	3994.
1939	1.	16.	62.	44.	98.	137.	44.	19.	5.	0.	0.	0.	426.
1940	0.	0.	4.	536.	1195.	840.	422.	94.	18.	6.	1.	0.	3116.
1941	0.	3.	260.	613.	1238.	1050.	1307.	256.	26.	10.	4.	1.	4768.
1942	1.	12.	328.	945.	864.	390.	572.	217.	19.	7.	2.	0.	3357.
1943	1.	58.	42.	1018.	394.	497.	187.	88.	16.	4.	1.	0.	2306.
1944	1.	7.	18.	33.	337.	316.	95.	55.	7.	0.	0.	0.	869.
1945	0.	13.	29.	70.	789.	273.	123.	94.	11.	2.	0.	0.	1404.
1946	0.	18.	725.	363.	154.	135.	110.	69.	11.	2.	0.	0.	1587.
1947	1.	35.	40.	40.	72.	163.	112.	43.	7.	1.	0.	0.	514.
1948	0.	2.	15.	14.	20.	119.	189.	90.	4.	0.	0.	0.	453.
1949	0.	0.	19.	21.	54.	856.	114.	80.	11.	1.	0.	0.	1156.
1950	0.	0.	12.	269.	300.	93.	75.	37.	5.	0.	0.	0.	791.
1951	0.	373.	865.	407.	333.	449.	106.	88.	17.	5.	1.	0.	2644.
1952	0.	6.	409.	1519.	678.	1063.	280.	98.	23.	8.	3.	1.	4088.
1953	1.	6.	480.	710.	127.	231.	96.	97.	12.	2.	0.	0.	1762.
1954	0.	22.	12.	142.	286.	287.	131.	54.	9.	1.	0.	0.	944.
1955	0.	5.	152.	255.	61.	110.	79.	54.	6.	0.	0.	0.	722.
1956	0.	0.	1564.	1049.	792.	337.	137.	74.	22.	8.	3.	0.	3986.
1957	1.	6.	11.	35.	361.	123.	81.	115.	6.	0.	0.	0.	739.

Table A8 (Continued)
Sunol Valley Local Inflow
Portion of Basin below San Antonio, Calaveras and Alameda Creek Dams
Excluding Sinbad and Vallecitos Creeks

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1958	0.	4.	39.	261.	1221.	1226.	1796.	215.	27.	11.	4.	1.	4805.
1959	1.	4.	13.	152.	513.	96.	51.	30.	5.	0.	0.	0.	865.
1960	0.	0.	5.	37.	257.	40.	31.	24.	1.	0.	0.	0.	395.
1961	0.	12.	11.	25.	19.	98.	22.	17.	1.	0.	0.	0.	205.
1962	0.	0.	10.	12.	727.	325.	74.	57.	8.	1.	0.	0.	1214.
1963	48.	2.	34.	759.	1033.	344.	660.	322.	21.	7.	2.	0.	3232.
1964	5.	73.	27.	248.	34.	64.	49.	33.	4.	0.	0.	0.	537.
1965	0.	16.	777.	1292.	213.	102.	512.	98.	18.	6.	1.	0.	3035.
1966	1.	76.	165.	135.	194.	99.	19.	22.	5.	0.	0.	0.	716.
1967	0.	13.	225.	867.	346.	769.	762.	337.	20.	7.	2.	0.	3348.
1968	2.	5.	28.	358.	174.	187.	96.	54.	7.	0.	0.	0.	911.
1969	0.	7.	90.	1255.	1402.	581.	204.	71.	23.	6.	1.	1.	3641.
1970	2.	5.	36.	829.	165.	546.	78.	40.	9.	2.	0.	0.	1712.
1971	0.	78.	623.	291.	41.	182.	109.	49.	12.	2.	0.	0.	1387.
1972	0.	1.	135.	42.	78.	29.	20.	10.	0.	0.	0.	0.	315.
1973	0.	243.	91.	862.	1406.	781.	168.	65.	17.	6.	1.	1.	3641.
1974	7.	149.	661.	638.	74.	647.	654.	107.	29.	14.	3.	0.	2983.
1975	3.	10.	33.	67.	1026.	1261.	371.	105.	26.	12.	6.	4.	2924.
1976	5.	7.	10.	9.	10.	42.	17.	7.	0.	0.	0.	0.	107.
1977	0.	0.	4.	17.	7.	25.	13.	9.	0.	0.	0.	0.	75.
1978	0.	0.	42.	989.	608.	790.	336.	89.	24.	6.	1.	1.	2886.
1979	0.	3.	9.	182.	553.	328.	120.	42.	6.	1.	0.	0.	1244.
1980	1.	12.	111.	889.	1587.	412.	171.	70.	19.	8.	2.	0.	3282.
1981	0.	1.	12.	455.	66.	446.	96.	35.	5.	0.	0.	0.	1116.
1982	0.	105.	200.	1038.	679.	531.	1610.	240.	25.	9.	3.	1.	4441.
1983	2.	94.	445.	1303.	1535.	2717.	647.	439.	40.	17.	7.	3.	7249.
1984	8.	212.	878.	116.	60.	110.	97.	83.	12.	3.	0.	0.	1579.
1985	0.	139.	52.	26.	118.	203.	31.	32.	7.	0.	0.	0.	608.
1986	0.	4.	17.	16.	1800.	1201.	228.	81.	20.	7.	2.	0.	3376.
1987	0.	0.	9.	16.	49.	72.	24.	8.	0.	0.	0.	0.	178.
1988	0.	0.	32.	62.	14.	17.	21.	10.	0.	0.	0.	0.	156.
1989	0.	0.	14.	15.	14.	86.	23.	7.	0.	0.	0.	0.	159.
1990	0.	14.	11.	35.	41.	39.	19.	14.	0.	0.	0.	0.	173.
EAR TOTAL	94.	2025.	12317.	25120.	34577.	29508.	16655.	5427.	808.	201.	53.	55.	126840.
YEAR MEAN	1.	28.	169.	344.	474.	404.	228.	74.	11.	3.	1.	1.	1738.

BOOKMAN-EDMONSTON ENGR., INC. 11/26/93

Table A9
Spills over Upper Alameda Diversion Dam

(ACRE FEET)

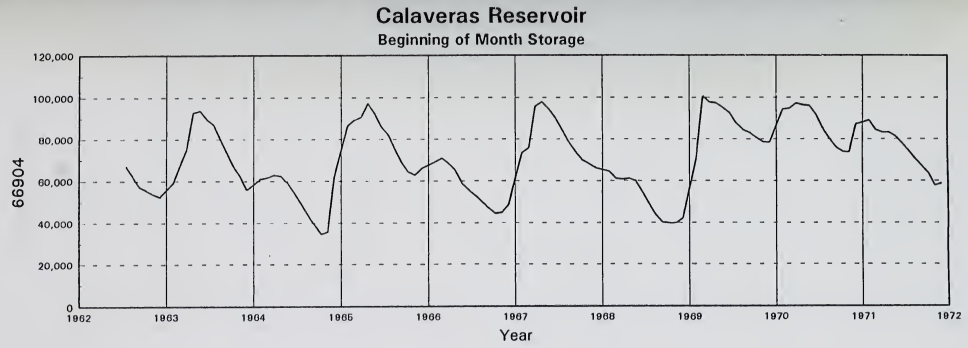
WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1918	0.	0.	0.	0.	0.	508.	0.	0.	0.	0.	0.	0.	508.
1919	0.	0.	0.	0.	5483.	998.	0.	0.	0.	0.	0.	0.	6481.
1920	0.	0.	0.	0.	0.	472.	413.	0.	0.	0.	0.	0.	885.
1921	0.	0.	429.	2212.	0.	0.	0.	0.	0.	0.	0.	0.	2641.
1922	0.	0.	470.	0.	6418.	160.	0.	0.	0.	0.	0.	0.	7048.
1923	0.	0.	1966.	229.	112.	0.	0.	0.	0.	0.	0.	0.	2307.
1924	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1925	0.	0.	0.	0.	562.	0.	0.	0.	0.	0.	0.	0.	562.
1926	0.	0.	0.	0.	4115.	0.	491.	0.	0.	0.	0.	0.	4606.
1927	0.	394.	0.	0.	1662.	0.	54.	0.	0.	0.	0.	0.	2110.
1928	0.	0.	475.	0.	190.	4698.	552.	0.	0.	0.	0.	0.	5915.
1929	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1930	0.	0.	0.	0.	0.	2930.	0.	0.	0.	0.	0.	0.	2930.
1931	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1932	0.	0.	1173.	0.	40.	0.	0.	0.	0.	0.	0.	0.	1213.
1933	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1934	0.	0.	0.	266.	0.	0.	0.	0.	0.	0.	0.	0.	266.
1935	0.	0.	0.	0.	0.	0.	124.	0.	0.	0.	0.	0.	124.
1936	0.	0.	0.	0.	1390.	0.	0.	0.	0.	0.	0.	0.	1390.
1937	0.	0.	0.	0.	457.	1472.	0.	0.	0.	0.	0.	0.	1929.
1938	0.	0.	256.	0.	6182.	1678.	0.	0.	0.	0.	0.	0.	8116.
1939	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1940	0.	0.	0.	51.	5636.	2050.	0.	0.	0.	0.	0.	0.	7737.
1941	0.	0.	0.	180.	1485.	895.	1695.	0.	0.	0.	0.	0.	4255.
1942	0.	0.	215.	1155.	3313.	1265.	0.	0.	0.	0.	0.	0.	5948.
1943	0.	0.	0.	1695.	0.	0.	0.	0.	0.	0.	0.	0.	1695.
1944	0.	0.	0.	0.	76.	0.	0.	0.	0.	0.	0.	0.	76.
1945	0.	0.	0.	0.	1047.	0.	0.	0.	0.	0.	0.	0.	1047.
1946	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1947	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1948	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1949	0.	0.	0.	0.	0.	25.	0.	0.	0.	0.	0.	0.	25.
1950	0.	0.	0.	0.	229.	0.	0.	0.	0.	0.	0.	0.	229.
1951	0.	0.	634.	152.	0.	0.	0.	0.	0.	0.	0.	0.	786.
1952	0.	0.	190.	3440.	177.	127.	0.	0.	0.	0.	0.	0.	3934.
1953	0.	0.	217.	240.	0.	0.	0.	0.	0.	0.	0.	0.	457.
1954	0.	0.	0.	0.	206.	0.	0.	0.	0.	0.	0.	0.	206.
1955	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1956	0.	0.	6293.	2803.	0.	0.	0.	0.	0.	0.	0.	0.	9096.
1957	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table A9 (Continued)
Spills over Upper Alameda Diversion Dam

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1958	0.	0.	0.	298.	2230.	915.	7300.	0.	0.	0.	0.	0.	10743.
1959	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1960	0.	0.	0.	0.	561.	0.	0.	0.	0.	0.	0.	0.	561.
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	1453.	0.	0.	0.	0.	0.	0.	0.	1453.
1963	120.	0.	0.	2966.	1327.	0.	69.	0.	0.	0.	0.	0.	4482.
1964	0.	0.	0.	294.	0.	0.	0.	0.	0.	0.	0.	0.	294.
1965	0.	0.	3067.	1453.	0.	0.	0.	0.	0.	0.	0.	0.	4520.
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	4451.	0.	435.	69.	0.	0.	0.	0.	0.	4955.
1968	0.	0.	0.	213.	0.	0.	0.	0.	0.	0.	0.	0.	213.
1969	0.	0.	0.	5319.	3292.	754.	0.	0.	0.	0.	0.	0.	9365.
1970	0.	0.	0.	1584.	0.	821.	0.	0.	0.	0.	0.	0.	2405.
1971	0.	0.	558.	0.	0.	0.	0.	0.	0.	0.	0.	0.	558.
1972	0.	0.	4.	0.	8.	0.	0.	0.	0.	0.	0.	0.	12.
1973	0.	43.	0.	1439.	4281.	0.	0.	0.	0.	0.	0.	0.	5763.
1974	0.	0.	1572.	0.	0.	688.	1189.	0.	0.	0.	0.	0.	3449.
1975	0.	0.	0.	0.	2293.	1844.	0.	0.	0.	0.	0.	0.	4137.
1976	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1977	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1978	0.	0.	0.	2966.	678.	1645.	0.	0.	0.	0.	0.	0.	5289.
1979	0.	0.	0.	126.	918.	0.	0.	0.	0.	0.	0.	0.	1044.
1980	0.	0.	0.	2953.	7824.	4.	0.	0.	0.	0.	0.	0.	10781.
1981	0.	0.	0.	1572.	0.	0.	0.	0.	0.	0.	0.	0.	1572.
1982	0.	0.	286.	4852.	3536.	2311.	2471.	0.	0.	0.	0.	0.	13456.
1983	0.	50.	1556.	1785.	4429.	9097.	0.	0.	0.	0.	0.	0.	16917.
1984	0.	100.	1293.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1393.
1985	0.	0.	0.	0.	689.	0.	0.	0.	0.	0.	0.	0.	689.
1986	0.	0.	0.	0.	9360.	3524.	0.	0.	0.	0.	0.	0.	12884.
1987	0.	0.	0.	0.	210.	0.	0.	0.	0.	0.	0.	0.	210.
1988	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1989	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1990	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
YEAR TOTAL	120.	587.	20654.	44694.	81793.	39392.	14427.	0.	0.	0.	0.	0.	201667.
YEAR MEAN	2.	8.	283.	612.	1120.	540.	198.	0.	0.	0.	0.	0.	2763.

Figure A-1


Calaveras Reservoir
Beginning of Month Storage
66904
120,000
100,000
80,000
60,000
40,000
20,000
0
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
Year

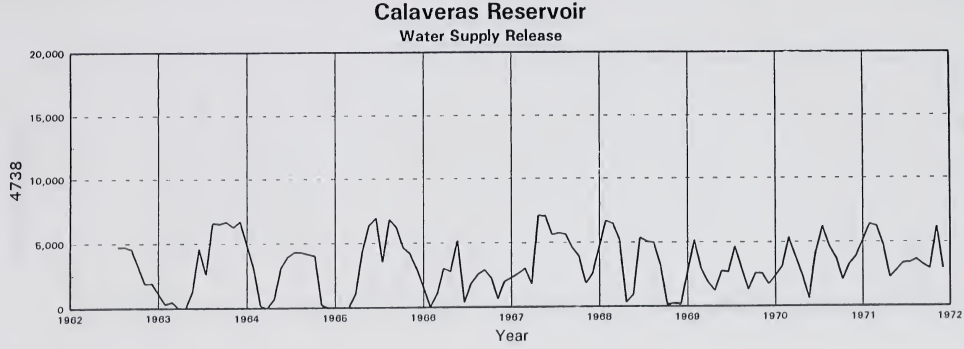
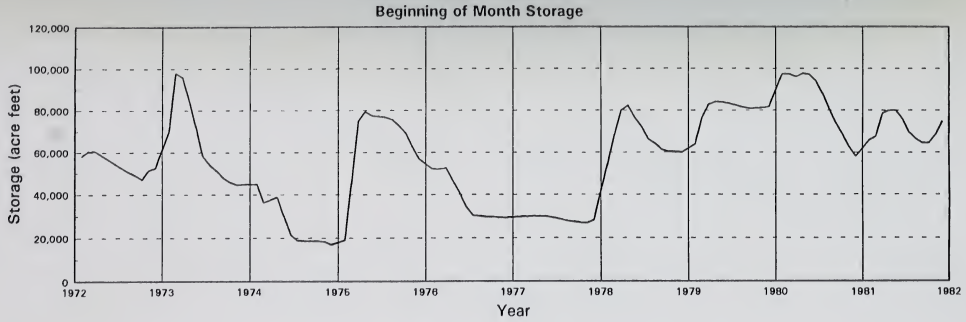
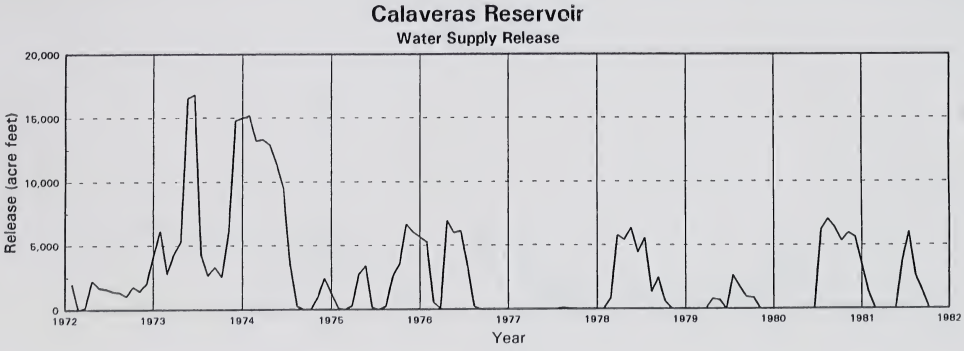

Calaveras Reservoir
Water Supply Release
4738
20,000
15,000
10,000
5,000
0
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
Year

Figure A-1 (Continued)





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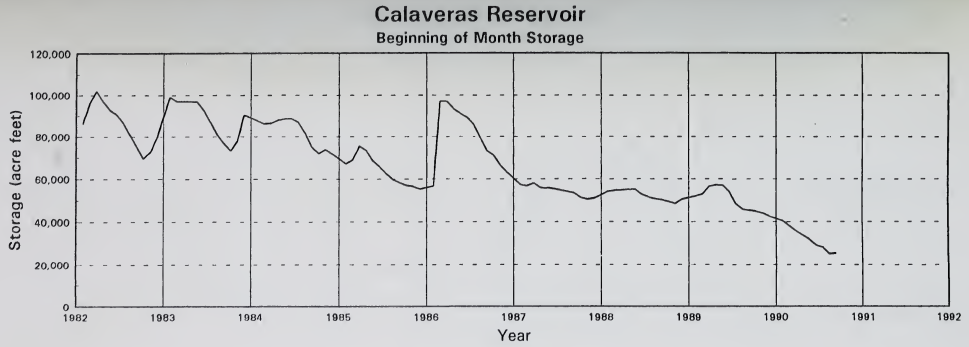


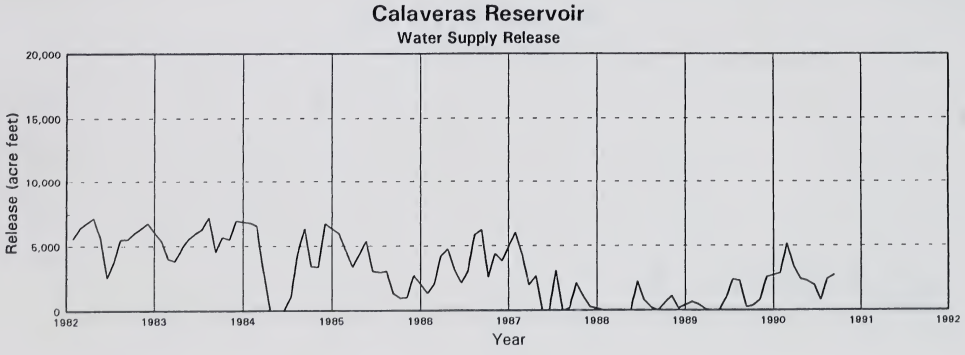
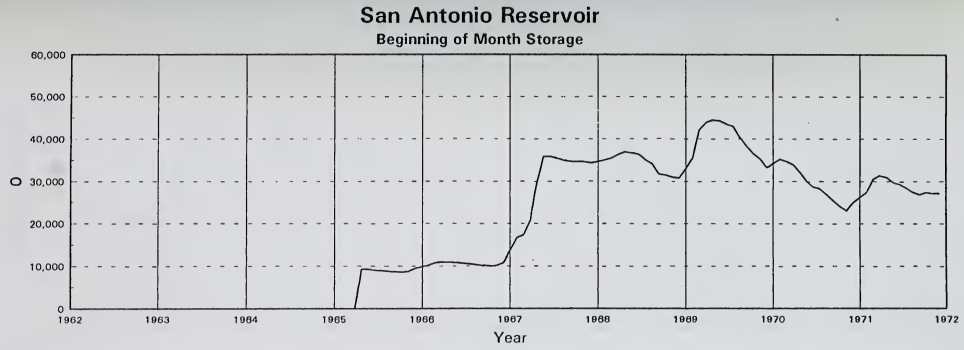


Figure A-2


San Antonio Reservoir
Beginning of Month Storage
60,000
50,000
40,000
30,000
20,000
10,000
0
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
Year

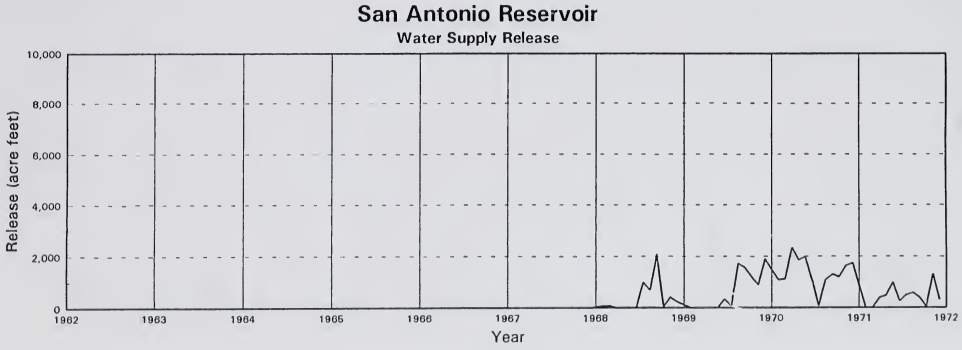
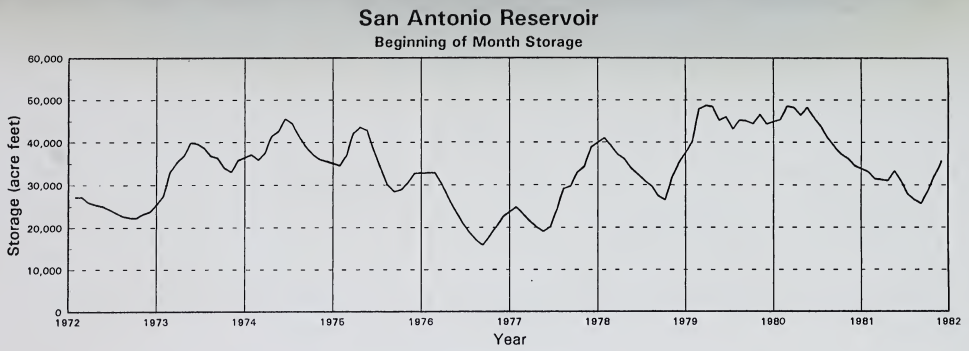

San Antonio Reservoir
Water Supply Release
10,000
8,000
6,000
4,000
2,000
0
Release (acre feet)
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
Year

Figure A-2 (Continued)



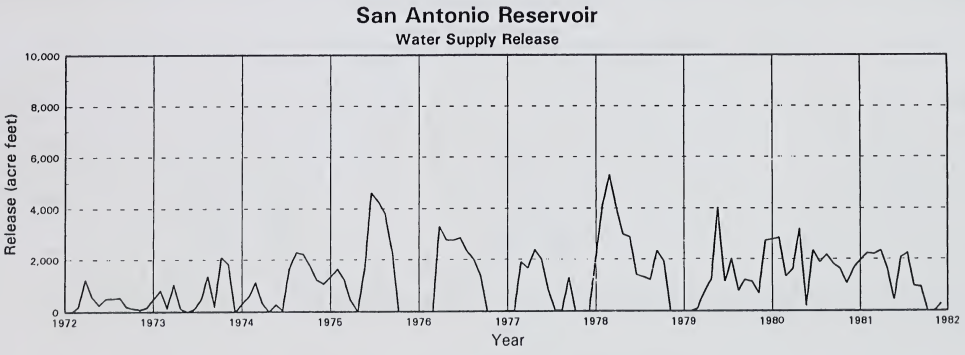
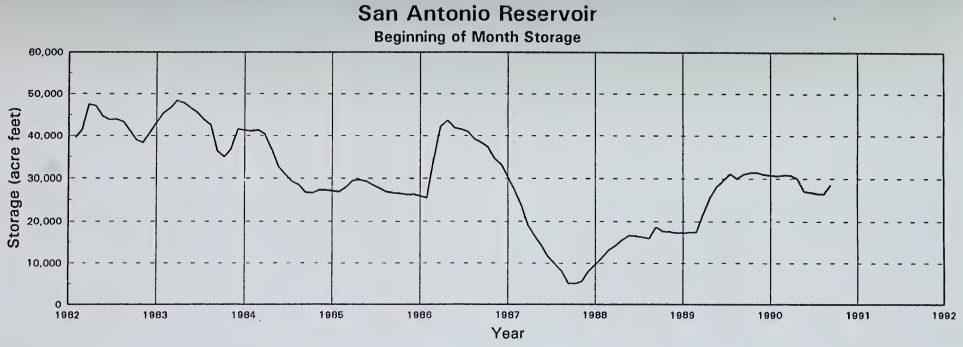
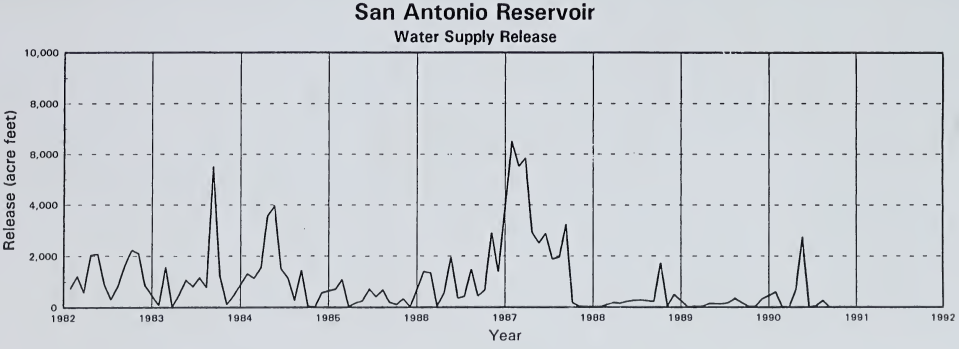


Figure A-2 (Continued)





APPENDIX G

GROUND-WATER AND AGGREGATE RESOURCES, SUNOL VALLEY JUNE 1994

Ground-Water and Aggregate Resources

Sunol Valley

prepared for
San Francisco Water Department

by

Luhdorff and Scalmanini
Consulting Engineers

under subcontract to
Bookman-Edmonston Engineering

December, 1993

92-2-001

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I. Introduction

In its request for proposal to provide engineering and hydrologic services for water resources planning in the Alameda Creek Watershed, the San Francisco Water Department listed four objectives in the planning study: 1) more efficient development and operation of Alameda Creek water resources facilities; 2) assessment of the feasibility of releasing a portion of water stored in Calaveras Reservoir via the streambed of Alameda and Calaveras Creek in order to create a trout fishery; 3) recapture of stream releases for consumptive use and to prevent inflow to the sand and gravel quarries in Sunol Valley; and 4) development of a plan for the Sunol Valley to guide the completion of quarry operations, focusing on additional water storage and recreational use of quarry lakes. Included with those objectives were tasks intended to address them. Relative to the hydrologic and quarry operations aspects of the overall project, those tasks generally included: identification of possible configuration of facilities to recapture any stream releases and to manage the subsurface flow of Alameda Creek upstream of the leased quarry operations; determination of impacts of quarry operations on water quantity and quality; and assessment of the potential impacts of future quarry operations on possible surface and ground-water development.

To address the above objectives and tasks, the scope of work for the interrelated hydrogeologic and quarry management components of this project was organized into five tasks: collection and review of geologic and hydrologic literature and data; data analysis, including a geologic assessment to identify the aquifer system, and hydrologic analyses of ground-water quantity and quality; development of alternative ground-water management strategies; development of a water resources conjunctive use plan, including alternative recapture facilities for stream releases; and development of a quarry management plan, with

focus on consistency among quarry operations, quarry reclamation, and potential water resource development.

In light of the above objectives and tasks, this summary report on the hydrogeology and gravel quarrying in the Sunol Valley has been divided into the following sections.

- **Geology and the Occurrence of Ground Water** which describes the geologic environment of the Sunol Valley and the formations which are aquifer materials of potential significance beneath the valley.

- **Ground-Water Hydrology** which describes the historical exploration and limited development of ground water, ground-water levels and the associated direction of ground-water flow, aquifer characteristics, potential well yields as part of a conjunctive use program or for recapture of live stream releases, and ground-water quality.

- **Quarry Operations and Management** which summarizes current and potential future mining, describes the relationship between quarry reclamation and water development plans, and defines alternative mining plans which can be grouped into an overall quarry management plan.

II. Executive Summary

The overall scope of the ground-water resource component of the Alameda Creek Water Resources Planning study was two-fold: 1) a geologic and hydrologic assessment to define and describe the occurrence of ground water, the characteristics of the aquifer system(s), and ground-water quality, and 2) development of a quarry management plan to describe historical and potential future aggregate mining, and to define alternative mining and reclamation plans consistent with water development plans, all relative to potential ground-water development and management as part of an overall surface and ground-water conjunctive use program. The overall conjunctive use plan could involve, as one component, the recapture of live-stream releases from Calaveras Reservoir via a cutoff wall and/or wells at an appropriate location near the Sunol Water Treatment Plant.

The geologic units in which ground water could occur in the Sunol Valley area are divisible into two main types: older geologic units, consisting of well compacted and lithified sedimentary rocks, generally considered non-water bearing to low water yielding; and younger geologic units, slightly compacted to unconsolidated, non-marine alluvial fan and stream channel deposits, of which the coarser-grained sand and gravel beds are considered water bearing. The deeper of the younger geologic units is the Livermore Gravels, which extend to depths of at least 500 feet below the Valley. Only a few wells have been completed into the Livermore, apparently due to its weakly compacted nature and fine-grained matrix content which limits porosity and permeability, and results in low water-yielding characteristics. Overlying the Livermore Gravels, to the ground surface, is a sequence of alluvial fan and stream deposited alluvium which is typically 30 to 40 feet thick. The alluvium has relatively high porosity and permeability, and is probably the most significant aquifer in the Valley.

There has been limited exploration and, for all practical purposes, there is essentially no development of ground water for water supply in the Sunol Valley. Significant ground-water related activities in the Valley include: operation of a shallow infiltration gallery behind Sunol Dam, from which water is pumped to San Antonio Reservoir and/or the Sunol Water Treatment Plant; intermittent diversion of water from Alameda Creek into spreading basins above shallow infiltration piping, which discharges through the Sunol Water Temple to the same pump station above; dewatering of inflow from the alluvium in the southern-most gravel mining excavation to maintain dry-pit mining operations; and mining operations behind slurry cutoff walls, which essentially stop inflow to the dry-pit mining operations, in the quarry excavations immediately south of Interstate 680.

Based on a small network of wells, most of which are small diameter monitoring wells, ground-water levels form a northerly gradient, approximately parallel to the ground surface. Essentially all the available or measurable ground-water level data is from wells completed in the shallow alluvium; and those data are of limited significance in light of the lack of ground-water development, and the limited thickness and depth of the alluvium.

An existing deep (407 feet) well was identified in the middle of the Valley as part of this project, and was selected for testing to define well yield and aquifer characteristics. The well and pump were reported by the owner/lessee, RMC Lonestar, to have historically pumped about 400 gallons per minute (gpm), but for less than typical municipal pumping cycles before water level drawdown reached the pump setting depth. Investigation of the well as part of this study confirmed it to be completed in both the alluvium and the Livermore Gravels. During subsequent testing of the well, only a 100 gpm discharge capacity could be maintained, although it caused a rapid water level drawdown. Aquifer transmissivity determined from that testing effort is very low, on the order of 3,000 gallons per day per foot (gpd/ft), suggesting that large scale ground-water development with medium to large capacity municipal wells as part of a conjunctive use program is not feasible in the Valley.

No testing of the alluvium was conducted as part of this study, primarily due to a lack of existing production wells completed in that shallow aquifer. Limited permeability tests reported by consultants to the quarry operators suggest that the transmissivity of the alluvium could be in the range of 15,000 to 45,000 gpd/ft. Well yields from an aquifer with such transmissivity values could be significant compared to the low yielding Livermore Gravels, but would be somewhat limited by the shallow depth and thickness of the alluvium. It is conceivable that, to recapture all the potential live-stream releases which could occur, 5 to 20 cubic feet per second depending on time of year, 20 to 60 wells and pumps would be required on fairly close spacing in and adjacent to Alameda Creek. Since the alluvium is both narrow and shallow near the water treatment plant, it would appear that recapture of stream flow could be more effectively and efficiently accomplished via a cutoff wall and low dam in the stream, with appropriate pump station, rather than a dense wellfield.

Ground-water quality considerations are less significant than originally envisioned due to the low potential yield of wells for municipal water supply. However, very limited data indicate that ground water beneath the Valley generally meets primary drinking water standards; there are no historical records of water quality data relative to secondary standards or organic compounds. There is no evidence that ground-water quality has been impacted at all by gravel quarry operations; but there is some evidence of impacts of agricultural practices, in the form of locally elevated nitrate concentrations, in shallow ground-water quality.

In light of the low apparent potential for ground-water development in the Valley, the historical and current aggregate mining activities have significant potential to create surface reservoir space for water resource use after mining. Reclamation to reservoir space has been a relatively minor objective of historical and existing mining; however, it is quite possible to now focus reclamation on that objective and achieve significant surface water storage space in the valley. In that light, four mining plan alternatives were developed in this study to recognize existing leases and mining permits, and to establish a framework for additional mining with the focused objective of creating reservoir space which can be

integrated into an overall surface water resource management plan for the Alameda Creek/Calaveras Reservoir/San Antonio Reservoir System. The four mining alternatives, and the potential reservoir storage space which can result from them are:

1) **Complete Existing Mining** - The Lonestar main pit, planned to be excavated to 140 feet, represents the most significant component of potential surface water storage, 12,000 acre feet. The smaller Lonestar Pit 1 and three smaller pits already mined to 40 feet to 100 feet represent a combined storage potential of about 4,000 acre feet. The 45 acre parcel recently leased and permitted by Lonestar is planned for reclamation to agriculture and currently represents no potential reservoir storage. Total potential storage volume on current Lonestar leases is about 16,000 acre-feet. Five permitted excavations leased to Mission Valley Rock immediately south of I-680 represent nearly 11,000 acre-feet of storage volume when mined to 140 feet as planned. The existing 70 acre lease north of I-680 represents an additional 4,000 acre feet; an interim moratorium has delayed the start of mining on that permitted lease, pending completion of this study. Completion of currently leased and permitted mining operations will result in about 27,000 acre-feet of storage south of I-680, and about 4,000 acre feet north of I-680.

2) **Extend Depth of Existing Mining** - In this alternative, all the currently leased and permitted parcels would be extended to a 200 foot mining depth. Total reservoir volume on the Lonestar leases would increase to 19,000 acre-feet; total storage volume on the Mission Valley leases would increase to 13,000 acre-feet south of I-680, and nearly 8,000 acre-feet north of I-680. Total storage volume would be about 40,000 acre-feet.

3) **Expand Existing Mining** (North and South of I-680) - In this alternative, areas not currently planned for mining south of I-680 would be mined; the 70 acre parcel north of I-680 would be expanded to 130 mined acres; and focus would be

placed on enlarging potential reservoirs by combining small pits and changing planned reclamation from agriculture to reservoir space. Total storage volume on the Lonestar leases would increase to about 24,000 acre-feet; the nursery area along Calaveras Road represents nearly 3,600 acre-feet; the Mission Valley leases south of I-680 would represent nearly 17,000 acre-feet, including the current Christmas tree farm area; and the storage volume north of I-680 would increase to about 23,000 acre-feet. Total storage volume would be about 68,000 acre-feet.

4) **Expand Mining South of Hetch Hetchy** - Two aggregate mining excavations south of the Hetch Hetchy aqueduct crossing would add about 11,000 acre-feet of reservoir storage volume to the total volume in any of the alternatives listed above.

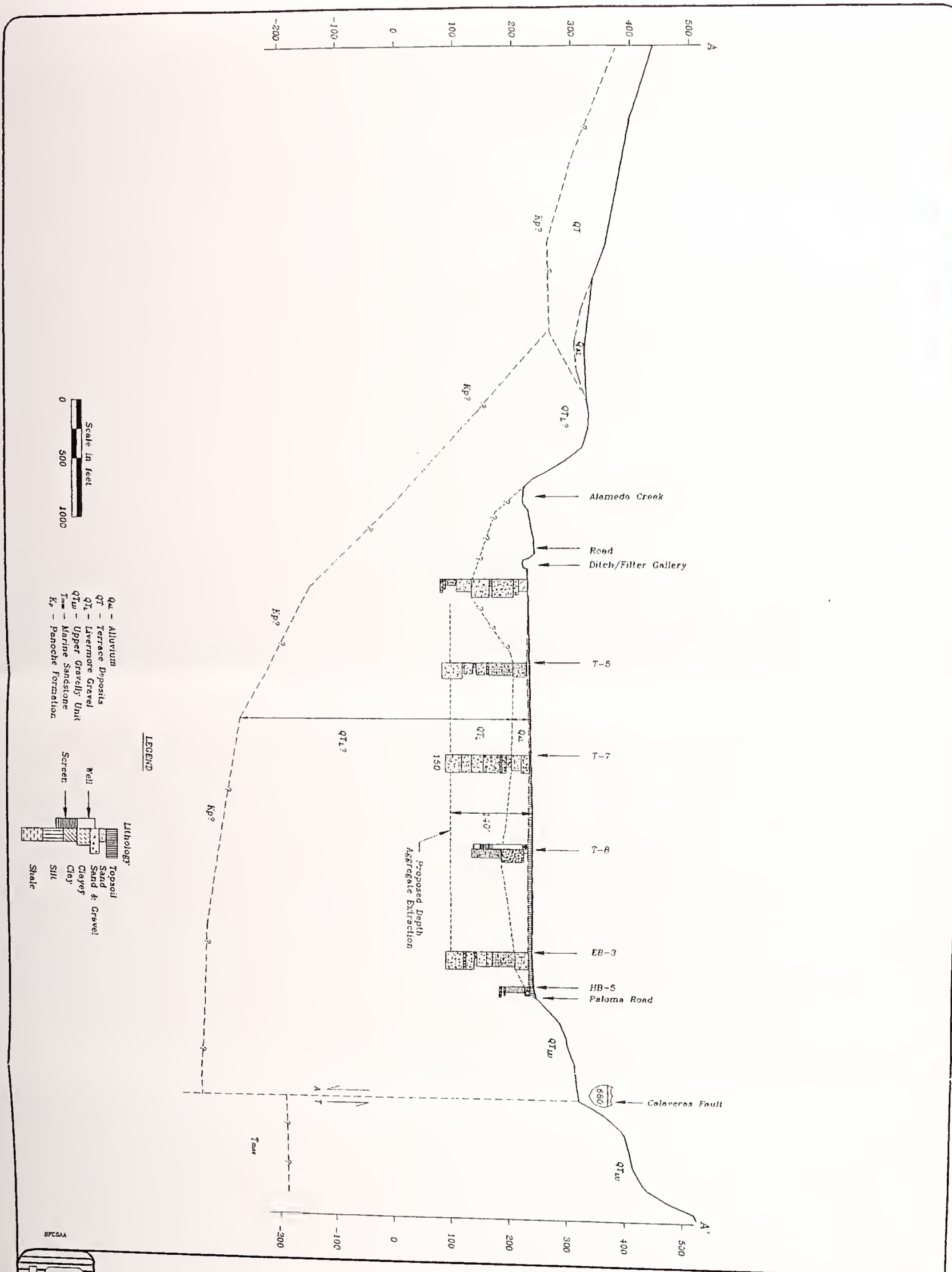
III. Geology and the Occurrence of Ground Water

Regional Geology

The regional geology of the project area is shown on the San Francisco-San Jose quadrangle sheet of the California Division of Mines and Geology (DMG, Wagner and others, 1990). Other geologic and hydrogeologic reports which encompass the area include: Hall (1959); California Department of Water Resources (DWR 1964, 1966, 1974); Helley and others (1972); Webster (1972); Herd (1978); Barlock (1988, 1989); and Ollenburger (1988). The most detailed geologic mapping consists of the three 7-1/2 minute quadrangles at a scale of 1:24,000 of the Niles, La Costa Valley, and Calaveras Reservoir (Dibblee, 1980 a & b; 1973). A simplified geologic map of the project area is shown in Plate 1 and geologic cross sections are shown in Figures 1 through 3.

The most prominent structural geologic feature of the project area is the Calaveras Fault. The Calaveras Fault is an active, right-lateral strike-slip fault where fault movement is dominated by horizontal motion with subordinate vertical offset (Herd, 1978). The trace of the fault is mostly concealed in the Sunol Valley area and upstream along Alameda Creek by recent stream-deposited alluvium and landslides (Herd, 1978). The fault zone is located along the eastern edge of Sunol Valley upstream to the Calaveras Road bridge crossing where the stream valley narrows. Upstream from that point, the fault follows the Alameda Creek channel, although still largely concealed by Alluvium. Further upstream, the fault zone is revealed as it leaves Alameda Creek and crosses several low ridge divides, trending south-southeast beneath Calaveras Creek and Reservoir (Dibblee, 1973).

Some previous reports (DWR, 1966; Herd, 1978; Wagner and others, 1990) have shown a



GEOLOGIC CROSS SECTION
A–A'

FIGURE 1

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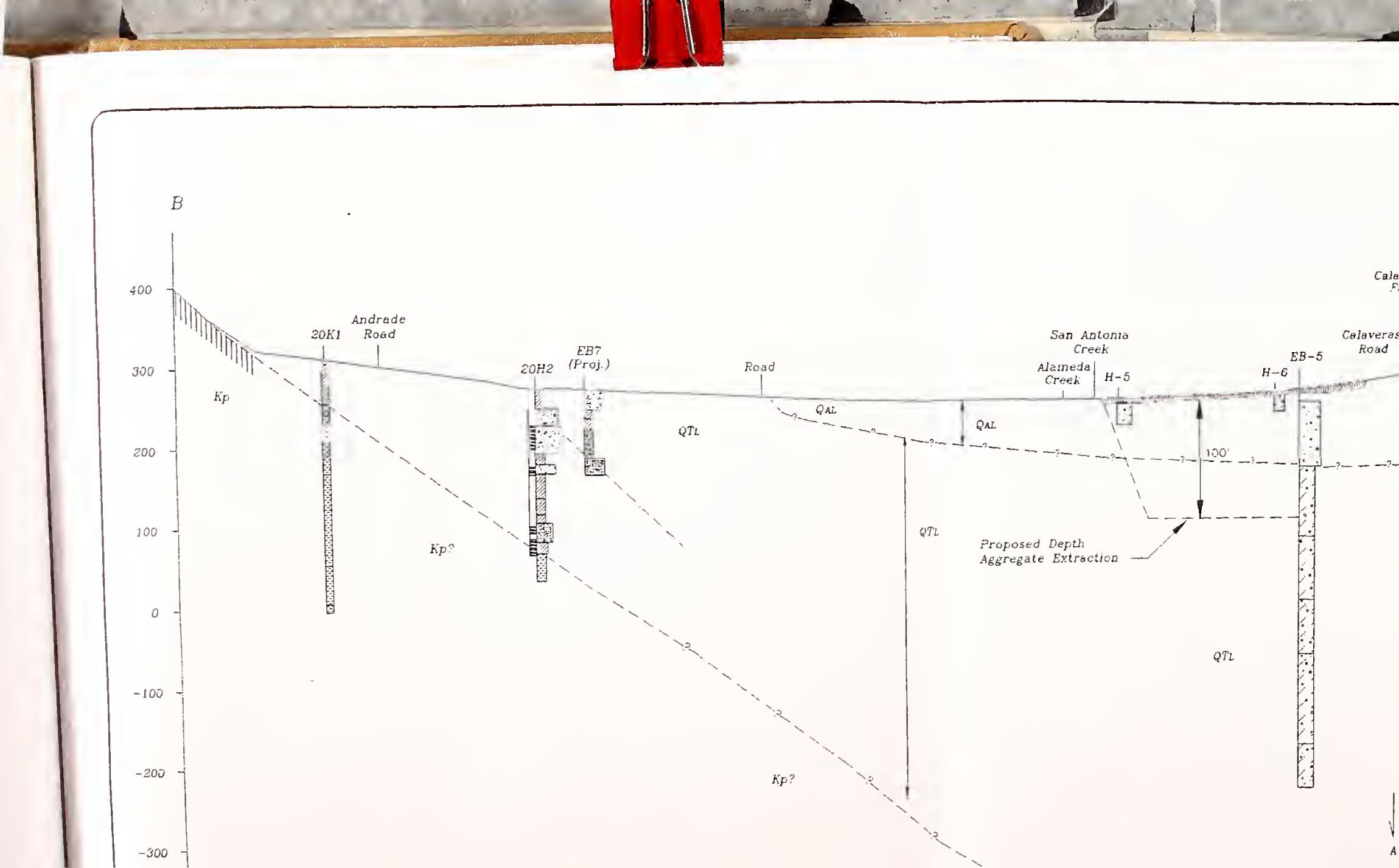
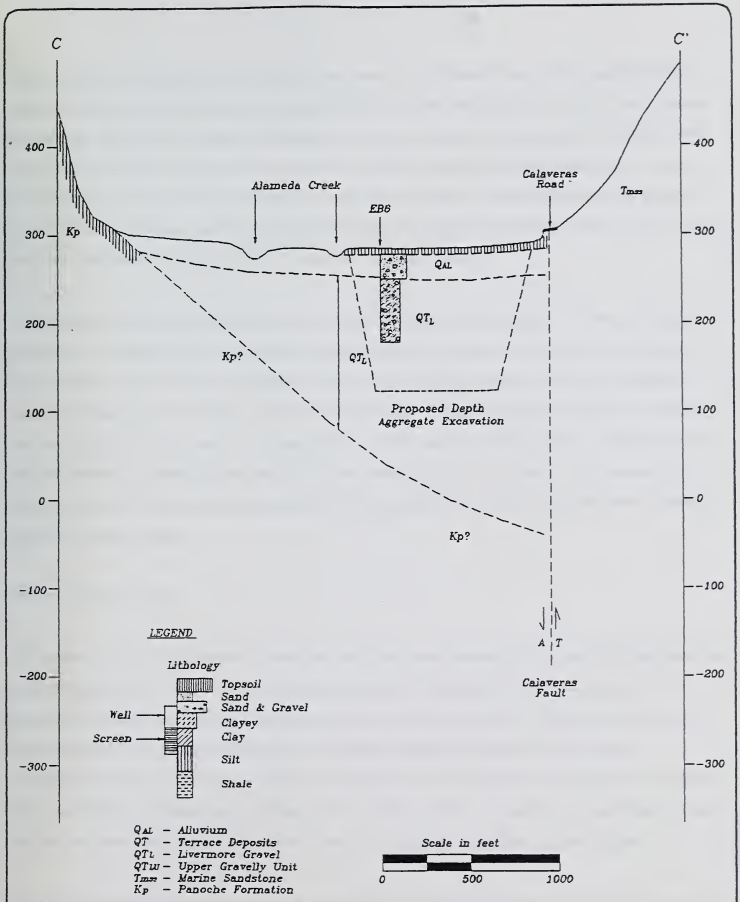

B
400
300
200
100
0
-100
-200
-300
20K1
Andrade Road
20H2
EB7 (Proj.)
Road
San Antonio Creek
Alameda Creek
H-5
H-6
EB-5
Kp
Kp?
QTL
QAL
100'
Proposed Depth Aggregate Extraction



SFGSCC

GEOLOGIC CROSS SECTION
C–C'

FIGURE 3

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fault along the western side of Sunol Valley, termed the Sinbad Fault. The fault is shown as concealed below the Alluvium, but truncated and aligned ridge spurs are taken as evidence of faulting. The fault is shown extending into faults mapped to the north and merging with the Calaveras fault to the south near the Geary Road-Calaveras Road intersection. Such a fault would explain the broad valley floor and some geologic configurations in the western Sunol Valley. However, other investigations have not mapped (Dibble, 1980 a & b), or have not found evidence of such a fault (Treadwell & Rollo, 1991).

The geologic units in the project area are divisible into two main types. Older geologic units consist of well compacted and lithified marine sedimentary rocks. These rocks, because of their compact nature, low permeability, and strong structural deformation are considered non-water bearing or at best very low water yielding. Younger geologic units, in contrast, are only slightly compacted to unconsolidated. These units are non-marine, alluvial fan and stream channel deposits of interbedded gravel, sand, silt and clay beds. The coarser-grained sand and gravel beds have high porosity and permeability and are considered water bearing and high water yielding.

Older Geologic Units

The older geologic (or bedrock) units are well compacted, consolidated, and lithified marine sedimentary rocks. The beds are strongly deformed, folded and have steep dips. These rocks are in some contrast on opposite sides of the Calaveras Fault. The oldest rocks are the Mesozoic Franciscan Assemblage consisting of highly deformed, deep marine sedimentary and volcanic rocks. These units occur east of the Calaveras Fault to the south near the Calaveras Reservoir (Cotton, 1972; Dibblee, 1973). Franciscan Assemblage rocks are not exposed west of the Calaveras Fault in the immediate Sunol Valley region.

The next younger of the bedrock units is the late Mesozoic (Cretaceous) Panoche Formation of deep marine origin consisting of shales with interbedded sandstones and conglomerates. East of the Calaveras Fault, the Panoche Formation is not present in the immediate Sunol

Valley region. West of the fault, extensive outcrop areas of the Panoche Formation occur along the hills bordering Sunol Valley, near the Calaveras Reservoir to the south, and in the hills north of Sunol. The Panoche Formation dips moderately to steeply westward.

The youngest of the bedrock units is the Tertiary (Miocene) Briones Sandstone comprised of shallow marine, calcareous sandstone with some fossil-rich conglomerates and shales. East of the Calaveras Fault from San Antonio Creek to Alameda Creek, the hills are underlain by the Briones Sandstone which is steeply dipping and complexly folded. West of the fault, the unit is dominated by siltstone and overlies the Panoche Formation in the upper hillslopes dipping moderately to steeply towards the west.

Younger Geologic Units

The younger geologic units are unconsolidated and weakly compacted to loose, non-marine, alluvial fan and fluvial sedimentary deposits. These units are mostly undeformed, showing only gentle dips and offset by active faults. The oldest unit is the Tertiary and Quaternary (Pliocene and Pleistocene) Livermore Gravels believed to be 5 million years to 100,000 (?) years old, although the younger age is poorly constrained. The Livermore Gravels are dominated by weakly compacted, thick, cobble to pebble gravel beds interlayered with sand and mudstone beds. The gravel and sand beds tend to have a variable amount of clay matrix reducing their porosity and permeability. In the project area, the Livermore Gravels are exposed to the east of the Calaveras Fault north of San Antonio Creek and extensively around the Livermore Valley. West of the Calaveras Fault, outcrop exposures are more limited around Sunol Valley. Limited subsurface data indicates that Livermore Gravels exist below Sunol Valley to depths of at least 500 feet (Figures 1 through 3). The Livermore Gravels have a largely unknown ground-water potential in the project area. Only a few wells extend into and produce from the Livermore Gravels. The weakly compacted nature and variable fine-grained matrix content in the sand and gravel beds may limit porosity and permeability to produce low water-yielding characteristics.

In the Sunol Valley and along stream channels, a sequence of younger (Pleistocene to Recent) alluvial fan and stream-deposited alluvium units exist. These units consist of unconsolidated gravel, sand, silt, and clay beds subdivided into older alluvium, younger alluvium and stream channel gravel and sand. Because of its loose nature, the alluvium has high porosity and permeability, and contains relatively large volumes of ground water which it yields readily to wells. The alluvium is probably the most significant ground-water aquifer in the project area.

Because of their importance, the Livermore Gravels and alluvium units are discussed in greater detail in the following section.

Alluvium - The alluvium in the Sunol Valley has been mapped into subdivisions based on topographic expression, relative elevations, soil development, and interpretation of relative age relationships. The most common mapping subdivision has been into four subunits: stream channel gravels (Qg); younger alluvium (Qa); older alluvium (Qoa); and terrace deposits (Qt) (Plate 1).

Steam channel gravels consist of sand and gravel occurring along the lowest level surfaces along current stream channels of Alameda and San Antonio Creeks, and other tributary streams. These deposits are thin unconsolidated sand and gravel probably interbedded with some thin beds of silt and clay. Younger alluvium consists of deposits underlying slightly higher topographic, gentle surfaces adjacent to the stream channels and covering the majority of the valley floor. These units probably are floodplain, steam channel, and alluvial fan deposits of slightly older age. At the surface, the deposits appear to be a finer-grained silt and clay unit of floodplain origin with soil profiles. Thickness of this finer grained unit is about 10 to 20 feet underlain by stream deposits of unconsolidated sand and gravel which are about 30 to 40 feet thick. Older alluvium occurs on slightly steeper slopes marginal to the valley sides and extending as gently rising alluvial fan surfaces. These deposits appear to consist of slightly older alluvial fan deposits of sand and gravel possibly with a thin soil development at the surface.

Terrace deposits occur at slightly higher topographic elevations above the older alluvium surface, and show a generally deeper dissection by erosion. The terrace deposits occur as isolated benches above the stream channels to the south. A large area on the northwestern edge of the Sunol Valley in the area of the Sunol Valley Golf Course (Plate 1) was mapped by Barlock (1988 & 1989) as terrace deposits. Barlock (1989) based the mapping on the lithology composition of gravel clasts. Previous investigators (DWR, 1966; Dibblee, 1980a; Helley & others 1972) had mapped this area as Livermore Gravels based on lithology and topographic expression. Barlock differentiated clast composition between the Livermore Gravels and these terrace deposits which indicated that they were of different age and origin. These terrace deposits consist of weakly consolidated sand and gravel beds probably of alluvial fan origin. If Barlock's interpretation is correct, no Livermore Gravels are exposed on the western side of the Sunol Valley.

Differentiation of the various alluvium deposits in the subsurface from borehole information is extremely difficult because of similar lithologic character. This difficulty is further complicated by the similarity between the alluvium and the underlying Livermore Gravel where present. Detailed geologic observations on clast composition and degree of consolidation during drilling operations may allow separation of the alluvium from the Livermore Gravels. Exposures in gravel pits may also indicate the contact between the alluvium and the more consolidated terrace and Livermore Gravels. Tentative geologic correlations from borehole information indicate that the thickness of alluvium deposits below the main portion of the Sunol Valley is about 40 to 60 feet. The loose, unconsolidated, and coarse-grained nature of the alluvium deposits indicate a high porosity, permeability and transmissivity. Ground water yield from the alluvium is probably the highest of all water producing units in the Sunol Valley.

Sand and gravel aggregate extraction pits in the Sunol Valley have encountered large volumes of ground water in the upper alluvium which requires dewatering. As further described and discussed below, one quarry operator has successfully resolved the ground-water problem by installing a slurry cutoff wall to depths of about 50 feet (through the

previous investigators mapped an area of Livermore Gravels (Dibblee, 1980a & b; Hall, 1958; Helley & others, 1972). However, Barlock (1988, 1989) indicates that these areas are landslide deposits of separate origin. It is possible that some of these areas are indeed Livermore Gravels, but detailed geologic field mapping would be required to resolve this question.

In the subsurface below Sunol Valley, several boreholes penetrated clayey sand and gravel deposits to depths of 500 feet without encountering bedrock (Figures 1 through 3). The character of these sand and gravel beds is poorly known, based mostly on a few water well driller's reports. Geophysical logs were run on at least one borehole, but that geophysical log was not available for this study. The areal extent and thickness of these sand and gravel beds is uncertain, as only a few boreholes extend to depths over 300 feet.

These sand and gravel deposits have been classified as Livermore Gravels (DWR, 1966, 1974). However, because of the limited exposures of the Livermore Gravels west of the Calaveras Fault, and the classification of the Terrace deposits near the Sunol Valley Golf Course (Barlock, 1988 & 1989), the thick sand and gravel deposits below the Sunol Valley floor may not be exclusively Livermore Gravels. Because of their described coarse grained nature (sand and gravel), these subsurface deposits appear to be most like the upper Livermore of Barlock (1989). However, their thickness of 500 feet or more is much greater than the measured thicknesses of the upper Livermore (200 feet). It is possible that structural warping or downdropping on the west side of the Calaveras Fault "captured" a thicker section of upper Livermore Gravels. The current flow directions and gravel size of the upper Livermore (Barlock 1989) indicate that the alluvial fan source may have existed in the Sunol Valley area during upper Livermore deposition. It is possible that some of the subsurface sand and gravels in the Sunol Valley may represent terrace deposits overlying upper Livermore gravel. Both of these possibilities would require detailed geologic assessment of clast composition from the subsurface to determine the affinity of the subsurface sand and gravels. For simplicity in this report, classification of the subsurface sand and gravel deposits below the Sunol Valley has been continued as Livermore Gravels,

although their actual affinity may be more complex.

Aggregate extraction pits in the Sunol Valley have extended to depths of 100 to 140 feet below the surface (Figures 1 through 3). As noted above, following shallow dewatering and/or cutoff walls to isolate the pits from the upper 50 feet or so of alluvium, little dewatering is required to reach total pit depths. Apparently the sand and gravel deposits below 50 feet are weakly consolidated or compacted and may have a high content of interstitial clays. This results in limited porosity and permeability and little ground-water flow into the aggregate pits. If these characteristics exist for all of the subsurface Livermore Gravels below Sunol Valley, it implies that deeper wells would be completed in aquifer materials with poor hydraulic characteristics, and would consequently have low yields.

IV. Ground-Water Hydrology

The objectives of the ground-water hydrologic components of this project were to review and summarize historical exploration and development of ground water in the basin, to analyze available ground-water level data and determine the general direction of ground-water flow, to estimate aquifer characteristics and determine potential well yields, and to summarize ground-water quality. Interrelated with the estimation of potential well yields and ground-water quality was to be consideration of potential conjunctive use of surface and ground water in the valley; however, in light of low aquifer transmissivity and associated low potential well yields discussed below, it was concluded as the study progressed that there are essentially no practical conjunctive use possibilities in the valley.

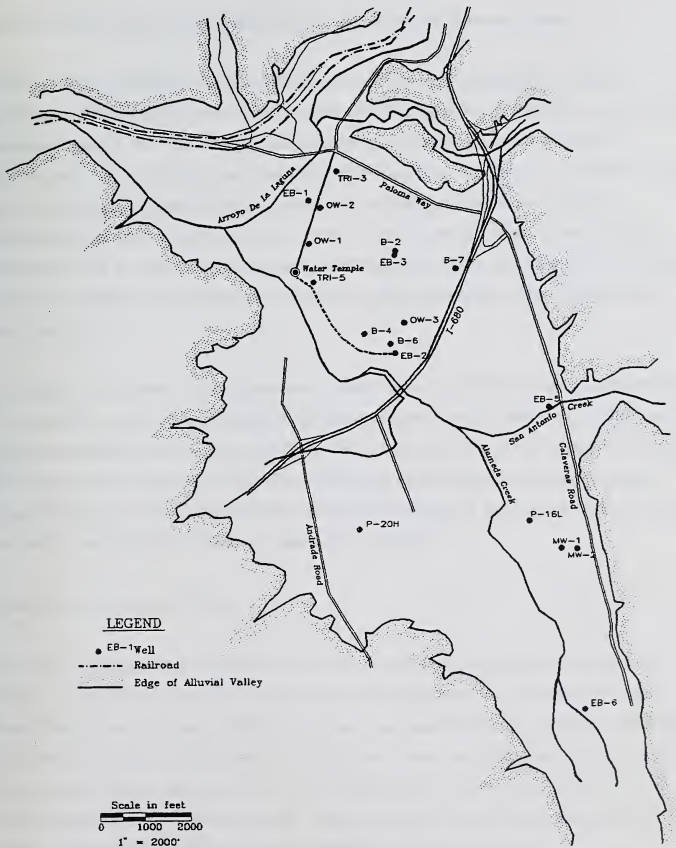
Historical Exploration and Development

The most notable development of ground water in the valley has been the original installation and operation of infiltration galleries above Sunol Dam and immediately above the Sunol Water Temple, originally by the Spring Valley Water Company prior to San Francisco's acquisition of the Alameda Creek watershed property and facilities. Sunol Dam was originally constructed to maintain hydraulic head on the surficial gravels beneath and adjacent to Alameda Creek immediately upstream of the dam; the resultant infiltration into the gallery piping beneath the creekbed was originally discharged into the Sunol Aqueduct to ultimately cross San Francisco Bay for water supply to the City. The infiltration gallery above the Water Temple is located off-stream beneath infiltration basins which can be filled with water diverted from Alameda Creek. The resultant infiltration, which occurs only when water is purposely diverted from the creek to the infiltration basin, discharges through the Water Temple to the downstream infiltration gallery piping described above. Under current

operations, the Sunol Aqueduct is no longer used for transport of water to cross the Bay (it merely serves six remaining customers of the City in the Niles Canyon below Sunol Dam); infiltration from the two gallery networks is discharged through the Sunol Pump Station, from which it can be directed to San Antonio Reservoir or the Sunol Valley Filtration Plant.

The majority of other historical ground-water exploration has been conducted by the gravel quarry operators, primarily Mission Valley Rock, for control of ground-water inflow to their quarry excavations. Since early excavations into and through the alluvium as part of aggregate mining, it has been recognized that the alluvium readily yields ground water but that the Livermore Gravels are apparently quite low in permeability, and possibly low in storage, resulting in essentially no ground-water inflow to the quarry excavations below the alluvium, but significant inflow from the shallow alluvium. That inflow was historically collected and used for plant process (Lonestar still uses such captured inflow for plant process; it has abandoned use of a well originally installed by Santa Clara Sand and Gravel well for water supply). Mission Valley Rock has successfully controlled the inflow of shallow ground water from the alluvium to its excavations via extensive local exploration drilling, monitoring well construction, permeability testing, and ultimately slurry cutoff wall installation through the alluvium around its excavations south of I-680. Although no excavation has been conducted north of I-680, Mission Valley has also conducted extensive exploration drilling, monitoring well construction, and permeability testing in that area as a basis for slurry cutoff wall design to be installed when its permitted operation expands to that location. The remaining monitoring wells on both sides of the freeway were used for field data collection in this study. Historical data (water levels, water quality, permeability) reported from those wells were also used in this study.

In terms of ground-water exploration and development for water supply, there are two known wells south of I-680 which penetrate the Livermore Gravels for water supply, one originally used for gravel processing by Santa Clara Sand and Gravel (now Lonestar) but now out of service, and one used for small capacity nursery irrigation west of the Mission Valley plant near Andrade Road. The Lonestar (Santa Clara Sand and Gravel) well was



Well Locations
Sunol Valley/Alameda Creek Area

FIGURE 4

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used for well and aquifer testing in this study, and is further discussed below.

Finally, in 1986, Alameda County Water District undertook an exploration effort to investigate potential ground-water storage, and recovery via wells, in the basin. That work proceeded through test hole drilling and monitoring well construction at six sites; unfortunately, the investigation stopped short of constructing and testing a production well which would have provided initial reference data regarding well yield and aquifer characteristics in the Livermore Gravels. Most of the Alameda County Water District's monitoring wells are still in place and were used with the shallow wells installed by Mission Valley for water level measurements, observation during well and aquifer testing, and for water quality data.

In summary, as this study began, there was a limited network of existing wells in the valley: two production wells and approximately 18 monitoring wells which had been constructed by different investigators for varying objectives. Not all the wells could be located in the field, and none has been retained as part of any ongoing ground-water data collection effort. Those which were located in the field are identified in Figure 4. and details about all wells previously reported in the valley are summarized in Table 1.

Ground-Water Levels and Flow

There is no ongoing effort to measure and record any ground-water data in the Sunol Valley. In reports prepared for various previous investigations, i.e. by Alameda County Water District and by Mission Valley Rock, one-time measurements of depth to water have been noted in various wells, almost all of which have been small diameter monitoring wells. For one group of four wells, there were two measurements in one year (1989) but no measurements have been since reported. The limited water level data extracted from reports, plus the data developed during this study, is included in Table 2.

Since all previously reported ground-water levels were for depth to water, a limited effort

TABLE 1
SUMMARY OF WELL DATA
SUNOL VALLEY/ALAMEDA CREEK AREA

WELL ID	WELL ID (CASING)	CONSLT	TOC ELEV (SURVEY) ft msl	TOC ELEV (EST) ft msl	DEPTH (LOG) ft	DEPTH (MEAS) ft	PERF INTERVAL ft	CASING DIA in
EB-1	TESTWELL B-1	Converse	238.36		100	100.5	70-90	2
EB-2	TESTWELL B-2	Converse	240.12		300		230-270	2
EB-3	TESTWELL B-3	Converse	239.56		100	93.5	70-90	2
EB-5	TESTWELL B-5	Converse	262.07		300		250-280	2
EB-6	TESTWELL B-6	Converse			100		70-90	2
B-2	HLA-B2	HLA		240.91	59.5	58.1	19-39	4
B-4	HLA-B4	HLA		243.32	79	72.7	18.5-58.5	4
B-6	HLA-B6	HLA		245.33	67.5	66.2	17-47	4
B-7	HLA-B7	HLA		242.25	58.8	53.9	18-38	4
OW-1	OW-1	HLA				26.2		4
OW-2	OW-2	HLA				29.7		4
OW-3	OW-3	HLA						4
TRI-3	TRI-3	Treadwell			70	68.0	20-50	2
TRI-5	TRI-5	Treadwell	241.92		70	69.4	20-50	2
P-16L			260.94		442		25-442	12
MW-1			264.82			41.8		2
MW-2						39.6		2
P-20H			273.38		240		46-208	12
NON-LOCATABLE WELLS:								
EB-4		Converse			100		70-90	2
EB-7		Converse			100		70-90	2
MV-1P		HLA			50		12.5-39	2
MV-3P		HLA			46		10-29	2
MV-5P		HLA			30		4-30	2
MV-6P		HLA			25		4-25	2

* TOC - Top of Casing

TABLE 2
SUMMARY OF WATER LEVEL DATA
SUNOL VALLEY/ALAMEDA CREEK AREA

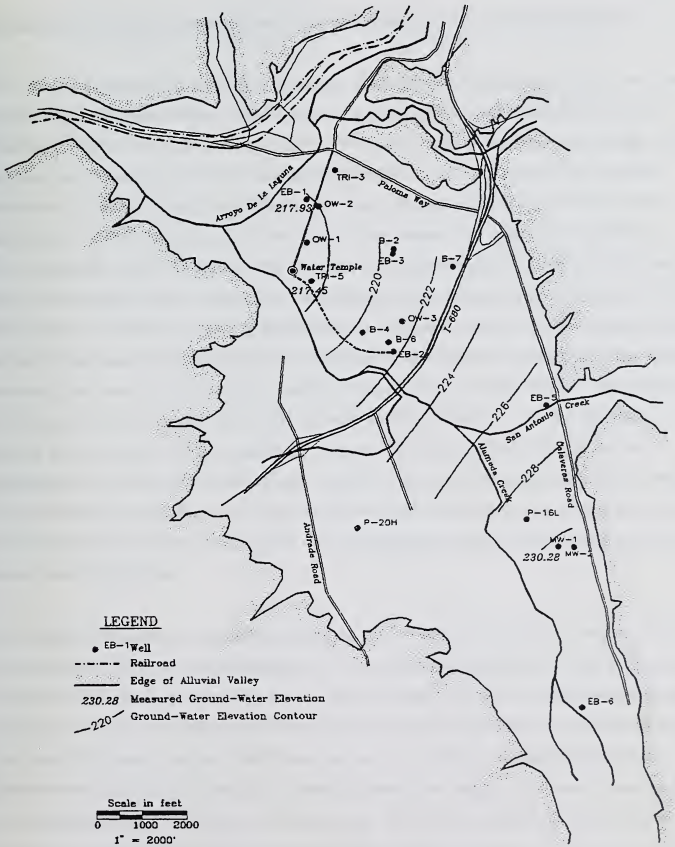
WELL ID	TOC* ELEV (SURVEY) ft msl	TOC ELEV (EST) ft msl	DTW* 09/10/86 ft	DTW 03/17/89 ft	DTW 10/11/89 ft	DTW 11/13/92 ft	DTW 6/04/93 ft	DTW 6/23/93 ft	GWEL* 09/10/86 ft	GWEL 03/17/89 ft	GWEL 10/11/89 ft	GWEL 11/13/92 ft msl	GWEL 6/04/93 ft msl	GWEL 6/23/93 ft msl
EB-1	238.36		16.7			20.43	20.35	20.44	221.66			217.93	218.01	217.92
EB-2	240.12		16.0			72.92	81.45		224.12			167.20	158.67	
EB-3	239.56		16.3			70.79	79.35	83.24	223.26			168.77	160.21	156.32
EB-5	262.07		48.0			72.87	78.71		214.07			189.20	183.36	
EB-6			27.7			26.67								
B-2		240.91		24.92	23.17	49.83		52.99		215.99	217.74	191.08		187.92
B-4		243.32		24.09	23.64	24.13		23.50		219.23	219.68	219.19		219.82
B-6		245.33		25.95	24.25	24.67				219.38	221.08	220.66		
B-7		242.25		26.81	25.51	28.76		27.69		215.44	216.74	213.49		214.56
OW-1						21.97								
OW-2						21.08								
OW-3						27.39								
TRI-3						23.32								
TRI-5	241.92					24.47		23.56				217.45		218.36
P-16L	260.94					29.99	25.85	25.46				230.95	235.09	235.48
MW-1	264.82					34.54	30.13					230.28	234.69	
MW-2						35.83								
P-20H	273.38						19.41						253.97	

* TOC - Top of Casing
DTW - Depth to Water
GWEL - Ground-Water Elevation

was undertaken in this investigation to survey selected wellheads in order to convert depth to water data into ground-water elevation data. That data was then used to develop a contour map of equal ground-water elevations for the period with the most complete record, Fall (November) 1992. At that time, the beginning of this study, water levels were measured in all wells that were identified from previous reports and which could be located in the field. As noted above, some of the reported wells could not be found in the field, presumably in most cases because they had physically been removed by mining operations.

The contours of equal ground-water elevations for Fall 1992 are illustrated in Figure 5 and generally indicate a direction of ground-water flow parallel to Alameda Creek and approximately parallel to ground surface contours on the valley floor. Such ground-water flow is as would generally be expected since there is essentially no net ground-water extraction over the majority of the valley; the only true "extraction" of ground water is via the City's infiltration galleries, plus any surfacing ground water which flows over Sunol Dam. It should, of course, be noted that shallow ground water is collected via drainage around the perimeter of the main Lonestar quarry excavation. A small amount of shallow ground-water seepage is also collected by Mission Valley Rock on the one side of its "New Lease" excavation that could not be isolated via a slurry cutoff wall due to the proximity of the South Bay Aqueduct. However, while that water is used for plant process, it is returned to the basin via settling ponds in the same area where some evaporation occurs. Overall, the gravel quarries' water use does not significantly affect the general pattern of ground water flow beneath the valley.

There are two items which should be noted relative to ground-water levels in the Sunol Valley: variations with time, and limitations of data with depth. In terms of temporal change, there is insufficient data on which to develop any firm conclusion. However, most of the limited data since 1986 (Alameda County Water District) and since 1989 (Mission Valley Rock) suggests that there are small seasonal (spring to fall) fluctuations and there have not been major changes in ground-water levels since those dates. Thus, it appears that the depth to shallow ground water is typically in the range of 20 to 30 feet, and that shallow



Ground-Water Elevation in Shallow Alluvium
November 1992
Sunol Valley/Alameda Creek Area

FIGURE 5

Luhdorff & Scalmanini Consulting Engineers

Sunol Valley Ground-Water & Aggregate Resources

92-1-001
August 1993

ground-water elevations and associated flow directions are as illustrated in Figure 5.

The notable exceptions to the above depiction of seasonal and longer term trends are three of the Alameda County Water District monitoring wells (EB-2, EB-3, and EB-5) and one Mission Valley Rock monitoring well (B-2). Wells EB-2, EB-3, and EB-5 are all 100 or 300 feet deep and screened below the base of the alluvium. Two of the wells had reported shallow water levels (16 feet) in 1986 and one had a deeper water level (48 feet) at that same time. All had water levels in the 70 to 80 foot range when measured in 1992 and 1993. Similarly, Well B-2, which is 59 feet deep and located adjacent to Well EB-3, had a deep (50 feet) water level compared to the original measurements of 23 to 25 feet in 1989. The deeper water levels in the EB wells might be indicative of the Livermore gravels, with the earlier measurements influenced by interaquifer communication during and after drilling; however, that would not explain the relatively constant shallow water levels in the other two remaining Alameda County Water District wells, EB-1 and EB-6. Also, the apparent decline at B-2, next to EB-3 is somewhat consistent with the decline in EB-3; but two considerations need further clarification: how water levels in B-2 declined to 50 feet, which is 11 feet below the bottom of the well screen; and how water elevations in that area north of Interstate 680 declined (if they were ever truly higher) in light of the lack of any deep ground-water extraction.

Any further investigation of existing monitoring well construction details or water level data was beyond the scope of this investigation. For purposes of the balance of this study, it was concluded from the majority of the monitoring well data, supported by observations in the quarry excavations, that shallow ground-water levels (in the alluvium) are typically 20 to 30 feet below the ground surface. Sufficient data are not available to exactly characterize ground-water levels in the Livermore Gravels; limited data suggests that static water levels in that formation were 70 to 80 feet in the last year. That latter conclusion, which appears supported by observations of the quarry excavation walls that extend to 140 feet and show limited to no saturated seepage, suggests that the alluvium/Livermore interface serves as a form of aquifer confinement, retarding any deep percolation of "recharge" to the Livermore.

It further suggests the possibility of a significant unsaturated zone beneath the base of the alluvium and the top of any Livermore Gravels "aquifer".

Aquifer Characteristics

Given the lack of ground-water development in the Sunol Valley from wells, it is not surprising that essentially no information on aquifer characteristics has previously been reported. The only exceptions are reported in investigations for Mission Valley Rock on both sides of Interstate 680 (Harding-Lawson Associates, 1987, 1989, and Treadwell & Rollo Inc., 1991). In both those investigations, slug tests were conducted in shallow monitoring wells to estimate the hydraulic conductivity of the alluvium; the calculated values were then used in the design of the slurry cutoff wall which now surrounds most of the Mission Valley Rock operation south of Interstate 680, and in the design of a slurry cutoff wall for future Mission Valley operations north of Interstate 680. Hydraulic conductivity values reported in those investigations ranged from 2.4×10^{-3} to 7.1×10^{-3} cm./sec. (50 to 150 gallons per day per foot^2). While those values are not pertinent to an analysis of potential well yields from the deeper Livermore Gravels as part of a conjunctive use program, they are useful in an analysis of wells potentially completed in the alluvium for recapture of live stream releases from Calaveras Reservoir as discussed below.

No aquifer characteristic information has been reported for the Livermore Gravels beneath the valley, which is not surprising since only two production wells are known to be completed in the Livermore in the entire valley. Of those two wells, one is equivalent to a small domestic well and is used for small capacity nursery irrigation; it is unlikely that any type of well or aquifer test would ever have been conducted on such a well. The other production well completed in the Livermore was reported to have been used for plant process water supply by Santa Clara Sand and Gravel about 20 to 30 years ago. It reportedly discharged several hundred gallons per minute at one time but, according to Lonestar (formerly Santa Clara) operation staff, the well could never discharge continuously for more than a few hours without breaking suction, suggesting that the aquifer has a

relatively low transmissivity.

In order to conduct a quantitative assessment of the Livermore Gravels relative to any potential conjunctive use program, i.e. planned ground-water recharge, storage, and recovery, it was recognized that some further development of data on that formation should be undertaken. As noted above, it was recognized that the 1986 conjunctive use investigation by Alameda County Water District had stopped just short of constructing and testing a production well after exploratory drilling and monitoring well installation. Thus, prior to this study, it was thought that an assessment of the Livermore Gravels would ultimately have to involve construction and testing of a well in order to develop certain baseline information about the deeper aquifer, i.e. saturated thickness, aquifer characteristics, well yield, potential pumping capacities, etc. Such basic information would also allow more quantitative assessment of one of the specific questions for this investigation: potential recapture of live stream releases via ground-water pumping. However, budget limitations for this project precluded new well construction as a component.

As an alternate to new well construction, the existing deep well on the site mined by Santa Clara Sand and Gravel (Lonestar) was selected for further investigation and testing. The well was constructed approximately thirty years ago and, according to the Water Well Drillers Report filed with the State, is completed only in the Livermore Gravels. The well was once a primary water supply for gravel plant operations; however, it is no longer in service, partly because sufficient water can be produced from the dewatering efforts in active excavations, and partly because the well did not provide sufficient yield for all plant operations by itself. Since the well was not operable and electrical service had been disconnected, an effort was undertaken to make it operational and conduct pumped well and aquifer tests to develop some of the baseline data delineated above. That effort included:

- remove the existing pumping equipment (electrical service had been disconnected and the existing electrical switchgear was in disrepair)

- conduct a video log inspection of the well structure to verify the reported construction details and examine its current integrity
- install a test pump and appurtenant test engine, discharge piping, meter, valving, etc.
- conduct limited "development" pumping to identify the approximate yield of the well and any problems, i.e. sand production, which might interfere with well testing
- conduct pumped well and aquifer testing over a period of approximately three days to determine well yield and aquifer characteristics and to investigate potential boundary conditions, i.e. recharge from any of the surrounding ponds, or the effects of the relatively nearby boundaries of the basin
- sample and analyze ground-water quality
- remove the test pumping equipment.

During removal, the existing pump was found to be completely sand locked, and it had experienced significant wear, all probably attributable to the lack of adequate sand control in the screened (perforated) section of the well. The video log inspection of the well structure closely verified the details in the Water Well Driller's Report: a 12 inch diameter casing assembly, 407 feet deep, with Mills knife perforations from 23 to 407 feet. The latter interval is mostly through the Livermore Gravels, the intended formation for testing; however, the upper 20 to 30 feet of perforations are opposite the shallow alluvium, which could potentially influence the results of any test intended to conclude about just the Livermore. Consequently, when a test pump was subsequently installed, provisions were made to operate it with and without a packer assembly to isolate the Livermore from the alluvium.

After pumping the well at three capacities for short periods to estimate its yield, two constant rate tests were conducted: one for 24 hours with no packer between the formations, and a second for 43 hours with a packer at 50 feet, immediately below the alluvium. In order to maintain the pumping water level sufficiently above the pump (installed at 200 feet), the discharge capacities were limited to 100 gallons per minute

(actually 95 gpm in the first test and 100 gpm in the second test). Both tests demonstrated steep drawdown curves, low well yields, and low aquifer transmissivity. A plot of drawdown vs. time through the longer test of the Livermore is illustrated in Figure 6; a plot of water level recovery vs. time for that same test is illustrated in Figure 7. Analysis of the pumped well test data indicates that the yield of the well, as measured by its specific capacity (discharge, in gallons per minute, per unit drawdown, in feet), is less than 1.5 gallons per minute per foot of drawdown. Such a value is extremely low for potential "municipal" wells which might be part of a San Francisco conjunctive use program. Aquifer transmissivity is also low, about 1,500 gallons per day per foot of aquifer width (gpd/ft.), based on the pumped well test data. Analysis of the recovery data yielded a slightly higher value of aquifer transmissivity, but the result, 3,200 gpd/ft., is still a low value.

The low yield of the tested well would suggest that high capacity recovery wells, as part of a conjunctive use program, would not be feasible. However, some question could be raised regarding specific flaws in the tested well which could influence the test data and results. For example, if aquifer transmissivity were high and well yield low, a problem with well efficiency could logically be suspected. However, since constant rate well testing and recovery observations are designed to eliminate the effects of well efficiency on test data for purposes of calculating aquifer characteristics, the resultant low transmissivity values are concluded to be representative of aquifer conditions in the Livermore, at least in the vicinity of the tested well. Also, based on general application of well hydraulic theory, the maximum yield (specific capacity) of a well completed in an aquifer with transmissivity of 1,500 to 3,000 gpd/ft. would be one to two gallons per minutes per foot of drawdown. That range of values suggests that the tested well results are consistent and that the well is not notably inefficient.

In light of the low aquifer characteristic values determined from the well tests, two notable conclusions relative to potential conjunctive use can be reached. First, it appears unlikely that high capacity wells could be installed and operated in the Livermore Gravels to recover stored ground water for water supply. Even assuming that the City was willing to operate

Figure 6
SUNOL AQUIFER TEST NO. 2
WELL P-16L

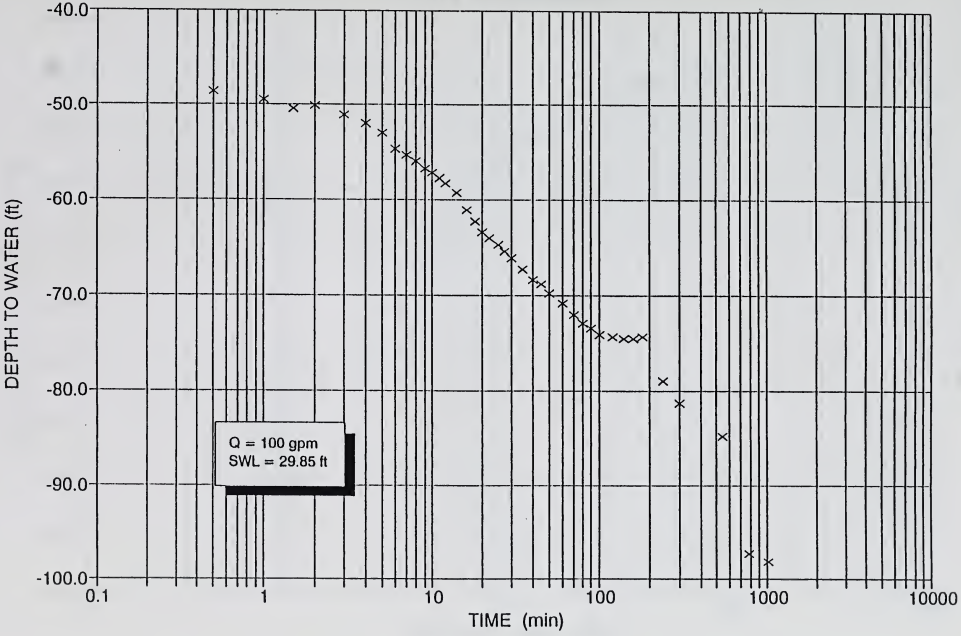
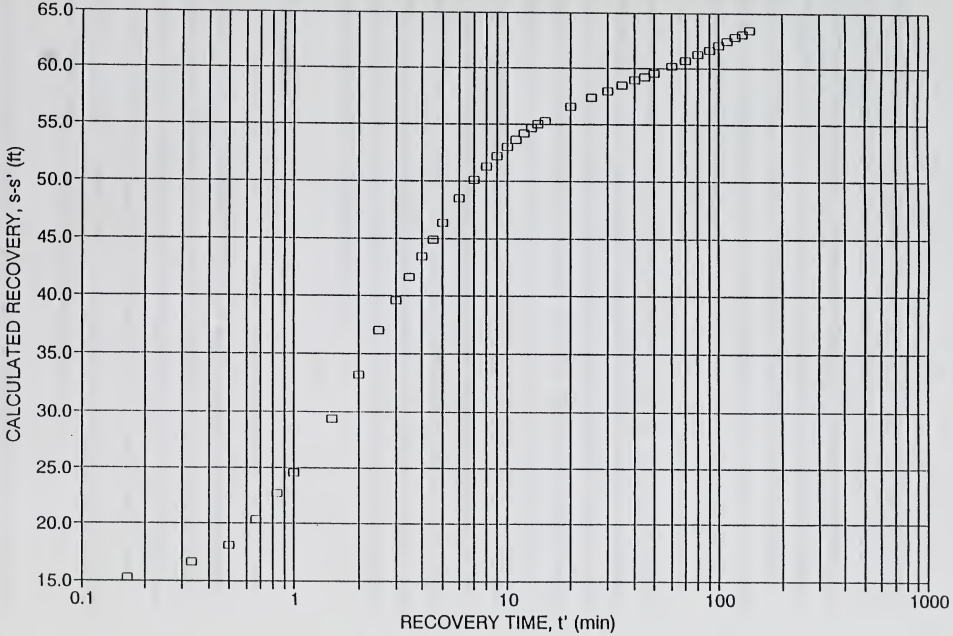


Figure 7
SUNOL AQUIFER TEST NO. 2
WELL P-16L RECOVERY



with deep pumping water levels to maximize capacity, i.e. pumping water levels of 300 to 350 feet with wells screened only in the lower portions of the Livermore, individual wells could only be expected to discharge up to possibly 400 gpm (less than one cubic foot per second). While some variation in aquifer characteristics and potential well yields might logically be expected in other locations of a sedimentary aquifer system, it is not likely, based on the limited available geologic data, that significantly better aquifer characteristics can be expected elsewhere in the valley.

A second conclusion relative to potential conjunctive use is that the low values of aquifer transmissivity suggest a limit to the recharge component of such an operation. Attempts to store water in the Livermore Gravels, either through surface spreading or injection, would be limited by the low transmissivity of the aquifer materials. Such is best demonstrated in current operations by the storage of water in finished excavations immediately adjacent to active mining. For example, at Mission Valley Rock where the shallow slurry cutoff wall controls any inflow from the surrounding alluvium, existing excavations extend to 140 feet but essentially no inflow or seepage occurs from the sidewalls excavated into about 100 feet of Livermore, even with an immediately adjacent excavation full of water to a comparable depth. Existing excavations into the Livermore Gravels serve effectively as reservoirs rather than as leaky recharge basins when filled with water.

Potential Well Yields

As discussed above, based on the results of well and aquifer testing in this investigation, it appears unlikely that any high capacity wells can be completed in the Livermore Gravels beneath the Sunol Valley. Maximum expected well capacities might be up to 400 gallons per minute. Those relatively low capacities, combined with deep pumping water levels, would result in low production capacity from a conjunctive use operation at a relatively high price in terms of both energy consumption and pumping costs.

Somewhat independent from conjunctive use with regard to well yields is the consideration

of potential recapture of live stream releases from Calaveras Reservoir after those flows had fully infiltrated from the streambed. As experimentally observed in another portion of this overall Alameda Creek investigation, releases of up to 30 cfs from Calaveras Reservoir fully infiltrated by slightly below the Sunol Valley Filtration Plant. One possible mechanism for recapture of those releases would be to pump the water from shallow wells, completed in the alluvium, to the treatment plant for ultimate delivery into the City's system.

Although no pumped well test data are available, and no wells were available for testing as part of this study, an attempt was made to estimate the potential yields of wells which might be completed in just the shallow alluvium for recapture of infiltration of stream releases near the treatment plant before it flowed as ground water down the valley toward the mining operations. The ultimate objective would be to recapture up to 20 cfs during peak stream releases in March to May.

The only available data on which to base estimates of shallow aquifer characteristics, on which in turn potential well yields can be estimated, are the hydraulic conductivity values derived from slug tests of monitoring wells, as described above in the process of designing slurry cutoff walls around the Mission Valley gravel excavations. A straightforward use of those conductivity values (50 to 150 gpd/ft^2), combined with an average saturated thickness of alluvium of 30 feet, suggests that the alluvium would also have a relatively low transmissivity, in the range of 1,500 to 4,500 gpd/ft. Such values suggest that well yields from the alluvium would also be low; specific capacities could be expected in the range of one to three gpm per foot of drawdown. While such low values of specific capacity are certainly possible, observations of flow from the alluvium where not restricted by cutoff walls suggest that the transmissivity of the alluvium is higher. Consequently, the slug test methodology was reviewed and discussed with the investigators for Mission Valley Rock. Based on the field methods which were employed, the previously reported values can be considered to be representative of vertical hydraulic conductivity, which is typically an order of magnitude less than horizontal hydraulic conductivity in an alluvial system. If that interpretation of the original tests is applicable, the transmissivity of the alluvium could be in

the range of 15,000 to 45,000 gpd/ft., which in turn would suggest potential well yields of 10 to 30 gpm per foot of drawdown.

The above aquifer characteristics were used in combination with the geologic description and measured water levels discussed earlier to design a "typical" alluvial extraction (recapture) well as follows:

- well depth (to base of alluvium) = 50 feet
- depth to static water = 20 feet
- saturated thickness of alluvium = 30 feet
- well screen interval (bottom one-third of saturated thickness) = 10 feet long, from 40 to 50 feet below the surface
- available drawdown during pumping (assuming no mutual pumping interference from the other recapture wells) = 15 feet (from static water level to five feet above top of screen)

Based on those parameters, the potential pumping capacity from a recapture well completed in just the alluvium could be less than 50 gpm if the reported values of hydraulic conductivity are actual. Optimistically, if the higher values of hydraulic conductivity discussed above are actual, potential pumping capacities could be in the range of 150 to 450 gpm per well. Obviously, further confirmation of shallow well yields and aquifer characteristics would need to be undertaken to refine consideration of wells for potential recapture of live steam releases after infiltration. Such confirmation, which should include well construction and testing, would also allow consideration of well spacing to effect recapture via a local regional pumping depression without adverse mutual pumping interference that would impact pump capacity and performance in individual wells.

Short of completing further well construction and testing in the alluvium, it can be concluded from this preliminary analysis that shallow wells could have to recapture as much

as 20 cfs (9,000 gpm) during peak release months. If well capacities are less than 50 gpm, 100 to 200 wells would be required for full recapture; such would appear to be completely impractical given the relatively small area available for the facilities. Even if the upper range of potential well capacity is achievable, resulting in discharges of 150 to 450 gpm per well, a recapture well network could require 20 to 60 wells, again a likely impractical approach.

In light of all the above, the following is a summary of findings relative to potential ground-water production in the Sunol Valley.

- aquifer characteristics and potential well yields are quite low in the Livermore Gravels, suggesting that ground-water storage cannot be likely achieved via infiltration or injection, nor can high capacity ground-water extraction likely be achieved.

- aquifer characteristics and potential well yields in the shallow alluvium could be better than the Livermore Gravels; but, even based on optimistic current estimates, recapture of peak live stream releases would require a well network of 20 to 60 wells.

- recapture of live steam releases would seem more logical via installation of a cutoff wall through the alluvium, comparable to those installed around some of the gravel excavations, and pumping from an infiltration gallery behind the wall; any "leakage" past the wall could be recovered by a few appropriately located wells.

Ground-Water Quality

The available data base relative to ground-water quality is somewhat comparable to, but more limited than, that described above for ground-water levels. As monitoring wells were installed for specific purposes, notably the Alameda County Water District exploration effort in 1986 and the Mission Valley Rock investigations for shallow ground-water control in 1987, 1989 and 1991, some ground-water samples were collected and analyzed for selected constituents. As part of this study, the well tested to determine well yield and aquifer

characteristics was also sampled and analyzed to determine ground-water quality.

In summary, all historical quality analysis have addressed some or all general mineral constituents, plus nitrate and boron in most cases; there have been no reports or documentation of general physical, inorganic, or organic constituents. A complete record of all known ground-water quality analyses in the Sunol Valley is summarized in Table 3.

The only known complete general mineral analyses of ground water in the valley were conducted on two samples from each of four monitoring wells installed by Mission Valley Rock in 1989, and on the sample collected from the well at the Santa Clara/Lonestar plant which was tested in this study. Less complete general mineral analyses were conducted on two samples collected from the Sunol Water Temple in 1984. Limited analyses were conducted as part of the Alameda County Water District investigation in 1986 (electrical conductivity, total dissolved solids, chloride, nitrate, and boron); and more limited analyses were part of Mission Valley Rock's monitoring north of Interstate 680 in 1990 (electrical conductivity and pH only).

Based on the data summarized in Table 3, ground water throughout essentially all the valley is generally comparable, with most concentrations of total dissolved solids in the range of about 350 to 500 milligrams per liter (mg/l). The ground water is generally a calcium-magnesium bicarbonate water, with all individual constituents generally low in concentrations. Nitrate concentrations, of some interest due to long term farming and nursery operations in the valley, have also been generally low; most reported concentrations have been in the range from one to about six mg/l (as nitrate), all well below the maximum contaminant level of 45 mg/l. However, there are two monitoring wells where nitrate concentrations have been quite elevated. At well B-2, located about in the middle of the field north of Interstate 680, nitrate concentrations were found in the range of 70 to 100 mg/l in 1989. Interestingly, an adjoining deeper well (EB-3) had a nitrate concentration of one mg/l in 1986. South of well B-2, well B-7 had reported nitrate concentrations of 62 and 177 mg/l in 1989. Both wells suggest some shallow impacts on ground-water quality from

TABLE 3
SUMMARY OF GROUND-WATER QUALITY DATA
SUNOL VALLEY/ALAMEDA CREEK AREA

WELL ID	DATE	EC	pH	TDS	CATIONS (mg/l) Ca	Mg	Na	K	ANIONS (mg/l) SO4	Cl	HCO3 as HCO3	CO3 as CO3	NO3 as NO3	B
		umhos/cm												
P-16L	06/24/93	880	6.9	570	110	35	41	1.8	68	40	380	ND	4.7	
EB-1	08/13/86	650		400						44			1	6.5
EB-2	08/18/86	980		570						108			1	9.8
EB-3	08/19/86	790		489						38			1	1.2
EB-4	08/12/86	680		437						26			10	1.0
EB-5	08/19/86	690		400						60			1	0.9
	08/20/86	690		440						58			1	1.0
EB-6	08/20/86	590		377						19			1	0.9
EB-7	08/12/86	3200		1823						830			3	7.0
	08/18/86	3150		1757						830			3	7.0
B-2	03/17/89	950	7.4	700	110	38	31	8.6	140	39	280	ND	71	0.4
	10/11/89	1000	7.0	670	110	45	28	2.8	125	35	280	ND	102	ND
B-4	03/17/89	700	7.5	370	69	23	36	2.3	84	41	220	ND	27	
	10/11/89	550	7.5	360	61	24	20	3.8	80	33	150	ND	4	0.2
B-6	03/17/89	620	7.2	390	69	36	24	5.4	78	26	210	ND	6	0.4
	10/11/89	520	7.5	330	61	30	22	5.2	54	26	170	ND	3	0.1
B-7	03/17/89	750	7.2	520	78	32	28	6.8	58	27	250	ND	62	0.3
	10/11/89	740	7.0	480	79	35	18	2.0	55	28	240	ND	177	ND
OW-1	01/08/90	460	6.7											
OW-1	01/08/90	480	6.8											
OW-1	01/08/90	460	6.7											
GP-1	01/08/90	500	6.8											
GP-2	01/08/90	420	6.8											
W.T.*	01/31/84	570	7.4	362	65	20	22		70	24				0.4
	09/18/84	657	7.3	404	74	27	26		70	26				0.4

* Water Temple

historical farming on the parcel.

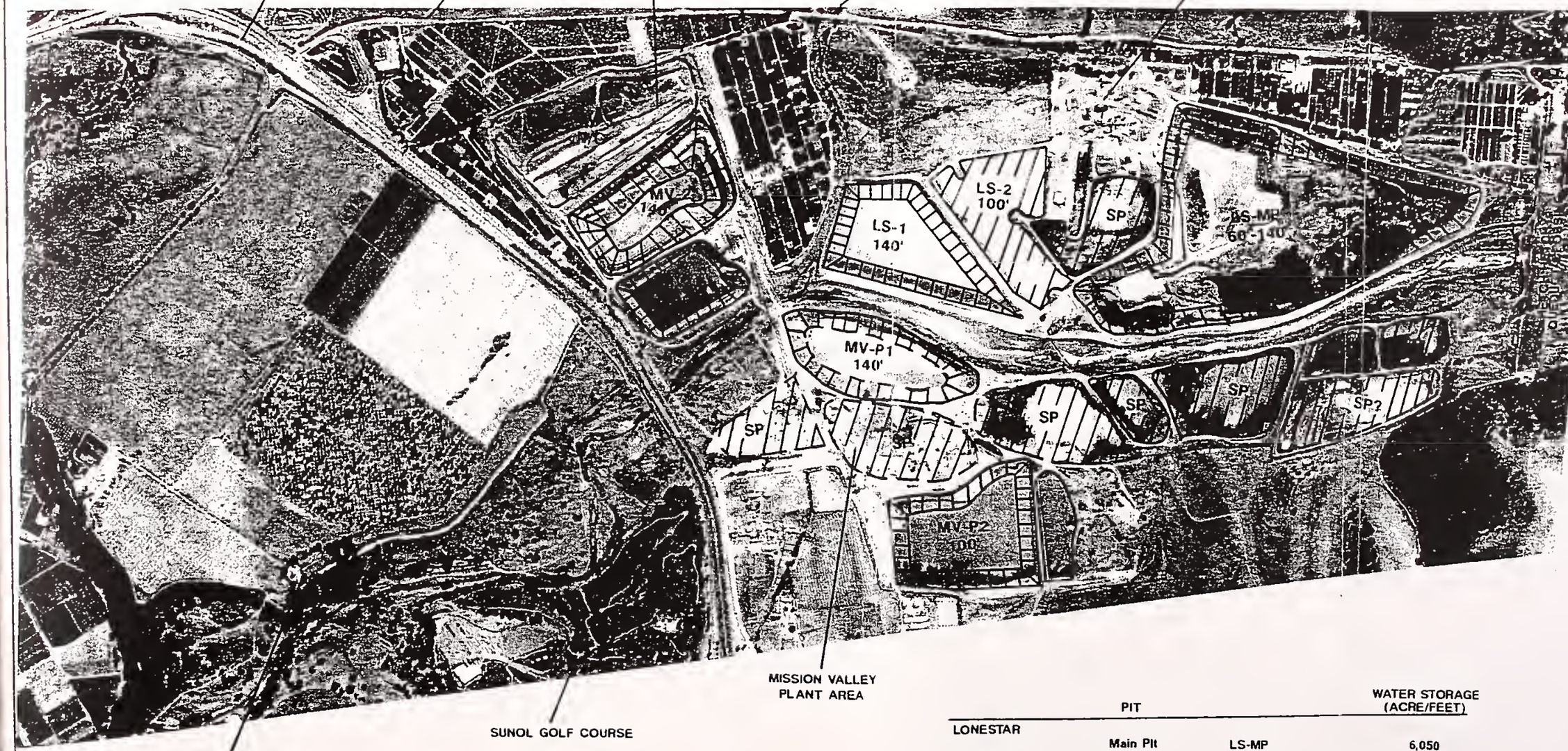
For unknown reasons, TDS concentrations have been found higher (510 to 700 mg/l) from two independent wells (B-2 and EB-3) located about in the middle of the field north of Interstate 680. That site is surrounded by other wells with TDS concentrations in the 350 to 500 (mg/l) range. The elevated TDS values may be related to historical agricultural practices, as also suggested by elevated nitrate concentrations in one of those wells (B-2) discussed above. Also, one of the Alameda County Water District monitoring wells, located near the southwest limit of the valley, had very high TDS (1,800 mg/l) and chloride (830 mg/l) concentrations; those samples may be influenced by a different geologic formation, but the results exceed secondary drinking water standards for those parameters. However, in light of conclusions relative to potential conjunctive use in the valley, those ground-water quality values are not expected to influence the future use of the valley for water resource management, which will probably involve quarry excavation followed by surface water storage.

V. Quarry Operations and Management

The objectives of this study relative to current and potential future gravel quarry operations in the Sunol Valley were to determine any impacts of existing mining operations on water resources and to assess the potential impacts of future quarry operations on possible surface and/or ground-water development. Included with the latter was to be a quarry management plan, with focus on consistency among quarry operations, reclamation, and potential water resource development.

Historic and Current Mining

Aggregate extraction from surface excavations has apparently been practiced on City property on the Sunol Valley floor since at least the early 1960's. Santa Clara Sand and Gravel Company apparently operated a quarry at that time on property south of Interstate 680 and east of the current alignment of Alameda Creek. That operation is currently conducted by RMC Lonestar, of which Santa Clara Sand and Gravel is a wholly owned subsidiary, on approximately 278 acres (117 acres mined). Alameda Creek apparently flowed naturally through the area now occupied by the largest Lonestar excavation (the "Main Pit" on Figure 8); the current creek alignment has been relocated along the western edge of the Lonestar excavations. Current Lonestar operations are governed by the original sublease between Santa Clara Sand and Gravel Company and San Francisco through the year 2000. That original lease was amended in 1993 to add 45 acres immediately north of the Lonestar plant for quarry excavation, backfill with fines from gravel processing, and reclamation to agriculture.



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WAC CORP.

AGGREGATE PIT
ACTIVE OR COMPLETE

SP

FORMER AGGREGATE PIT
USED FOR SEDIMENTATION
BASIN - FILLED WITH
CLAYS & SILTS

PIT			WATER STORAGE (ACRE/FEET)
LONESTAR			
	Main Pit	LS-MP	6,050
	No. 1	LS-1	2,550
	No. 2	LS-2	Sediment Basin
			Lonestar Total 8,600
MISSION VALLEY - NEW LEASE AREA			
	Pit 1	MV-1	1,200
	Pit 2	MV-2	2,300
	Pit 3	MV-3	Not Complete
			Mission Valley Total 3,500
			Option A Total 12,100
MISSION VALLEY - PLANT AREA (Not CCSF Property)			
	Pit 1	MV-P1	1,650
	Pit 2	MV-P2	2,000
			Total 3,650

FIGURE 8

Extent of Current Mining
Sunol Valley/Alameda Creek Leases

Sunol Valley Ground-Water & Aggregate Resources

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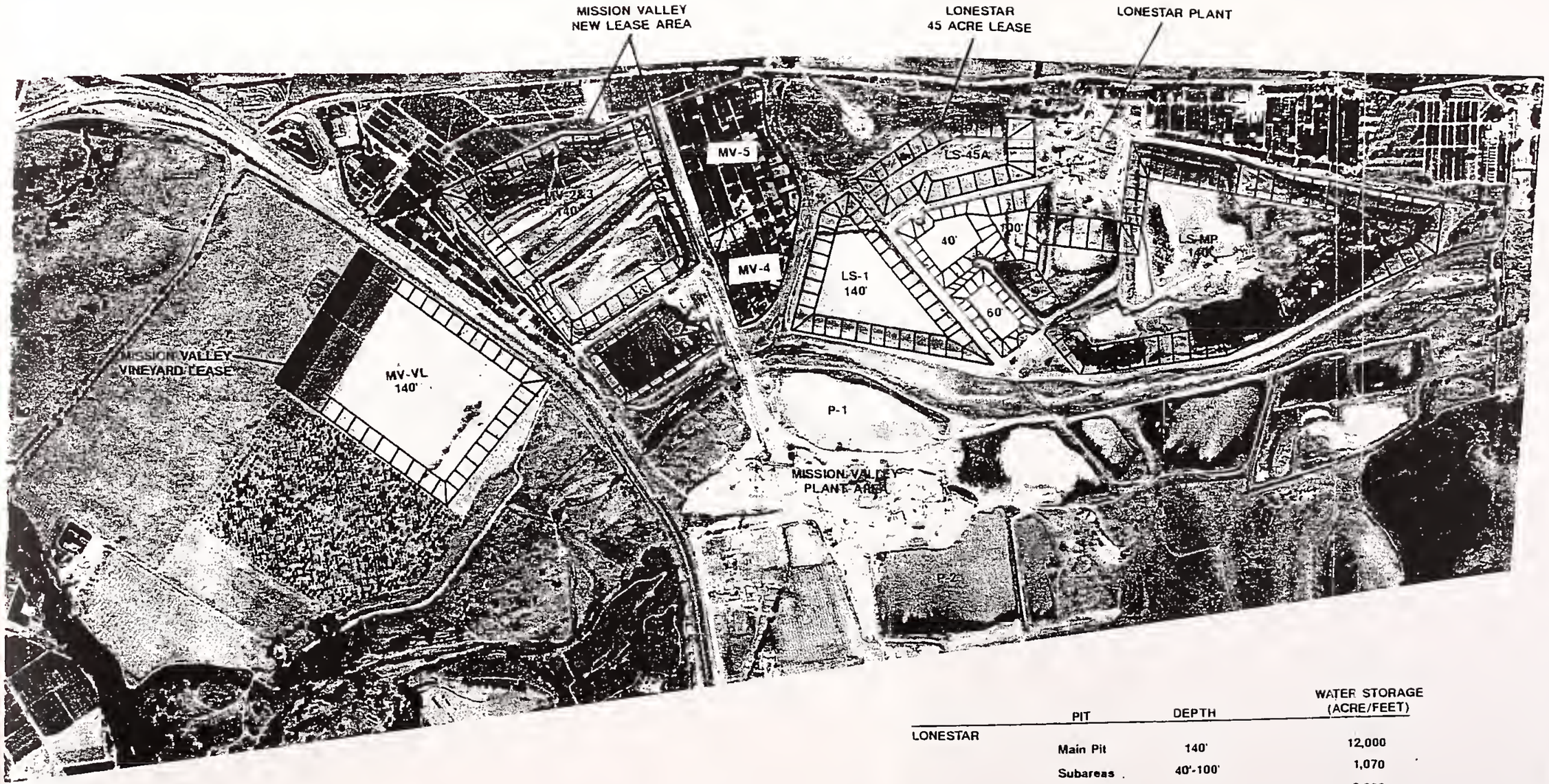

PIT		DEPTH	WATER STORAGE (ACRE/FEET)
LONESTAR			
	Main Pit	140'	12,000
	Subareas	40'-100'	1,070
	Pit 1	140'	3,030
	45 Acre Lease		Sediment Pond
		Lonestar Total	16,100
MISSION VALLEY - NEW LEASE AREA			
	Pit 1	140'	1,200
	Pit 2 & 3	140'	6,900
	Pit 4	140'	380
	Pit 5	140'	2,300
		New Lease Subtotal	10,780
MISSION VALLEY - VINEYARD LEASE			
	MV-VL	140'	4,130
		Mission Valley Total	14,910
		Option B Total	31,010

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WAC CORP.

AGGREGATE PIT
ACTIVE OR COMPLETE

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FORMER AGGREGATE PIT
USED FOR SEDIMENTATION
BASIN - FILLED WITH
CLAYS & SILTS

Completion of Existing
Leased and Permitted Mining

Sunol Valley/Alameda Creek Leases

Sunol Valley Ground-Water & Aggregate Resources

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FIGURE
9

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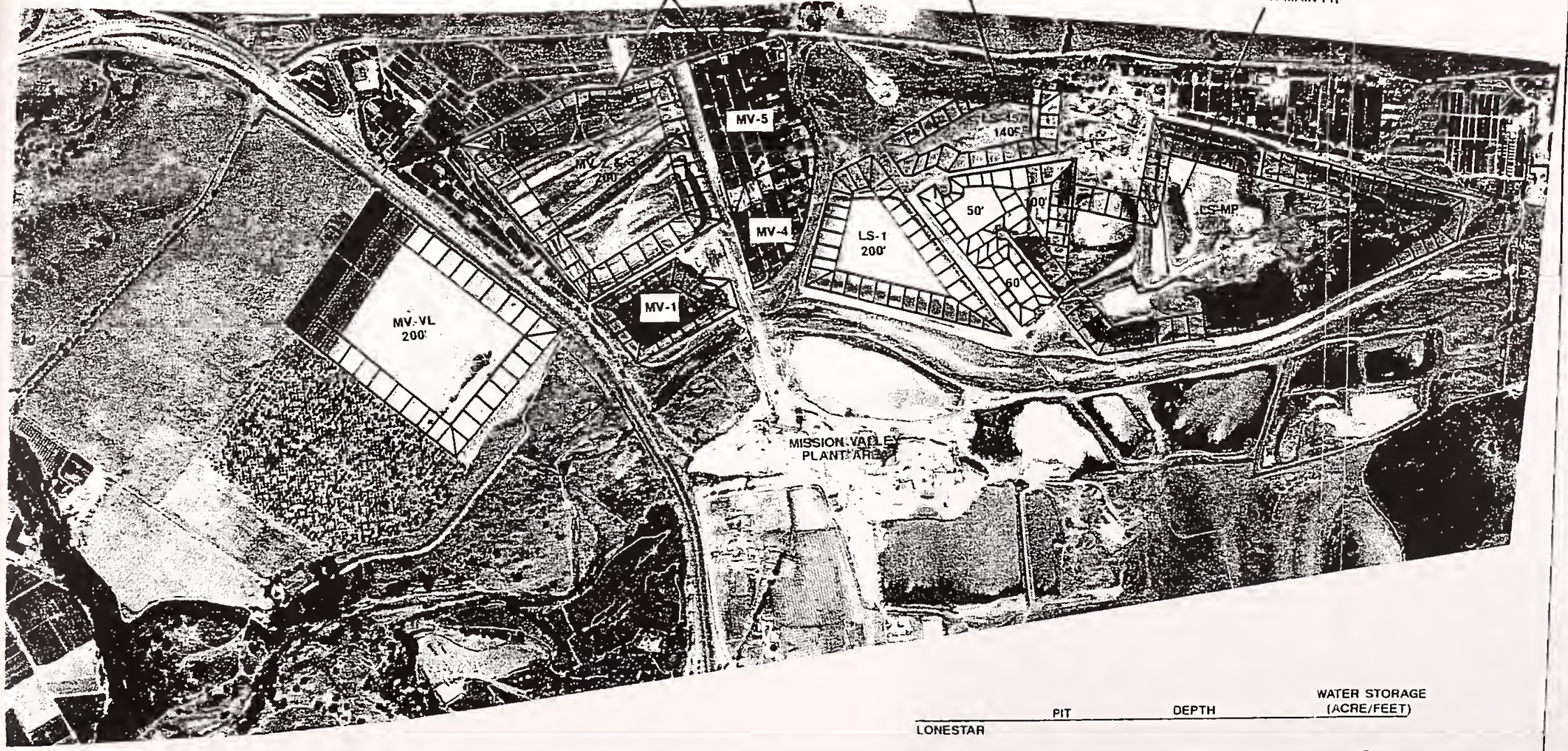

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WAC CORP.

AGGREGATE PIT
ACTIVE OR COMPLETE

SP

FORMER AGGREGATE PIT
USED FOR SEDIMENTATION
BASIN - FILLED WITH
CLAYS & SILTS

	PIT	DEPTH	WATER STORAGE (ACRE/FEET)
LONESTAR			
	Main Pit	200'	14,700
	Subareas	50'-100'	1,070
	Pit 1	200'	3,630
	45 Acre Lease	140'	Sediment Pond
		Lonestar Total	19,400
MISSION VALLEY			
	Pit 1	200'	1,560
	Pit 2 & 3	200'	8,300
	Pit 4	200'	700
	Pit 5	200'	2,500
		New Lease Subtotal	13,060
MISSION VALLEY - VINEYARD LEASE			
	MV-VL	200'	7,600
		Mission Valley Total	20,660
		Option C Total	40,060

FIGURE
10

Extension of Existing Mining
to 200 feet
Sunol Valley/Alameda Creek Leases

Sunol Valley Ground-Water & Aggregate Resources

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The exact history of Mission Valley Rock aggregate operations in the Sunol Valley was not researched for this study. However, it appears that Mission Valley conducted quarry operations for some time prior to 1985 on property south of Interstate 680 and immediately west of Alameda Creek. In 1985, Mission Valley subleased approximately 135 acres of San Francisco property, immediately south of Interstate 680 and east of Alameda Creek, for sand and gravel extraction (Mission Valley "New Lease" on Figure 8); that parcel was part of a larger, 204 acre, lease between San Francisco and G. Armanino & Son for vineyard, row crop, and rock quarry use during a lease period of March, 1985 through October, 2012. Subsequently, in 1986, the entire 204 acre lease was assigned to Mission Valley; the most significant component of that lease assignment was the addition of approximately 70 acres for future mining by Mission Valley immediately north of Interstate 680 and east of Alameda Creek (the "Vineyard Lease"). A voluntary moratorium on the commencement of quarrying on that parcel is apparently in effect until completion of this study.

Surface mining to date along Alameda Creek has resulted in several excavations immediately west of the creek, all but two of which have been filled with "fines" (clays, silts, and the non-salable byproducts of mining and processing) to original grade. The existing Mission Valley processing plant is located on such a reclaimed excavation. Two remaining excavations west of the creek are currently used for deposition of process wash water and fines. Current Mission Valley operations are in a third excavation on the "New Lease" (assignment from Armanino) immediately south of Interstate 680 and east of Alameda Creek, across the creek from the plant site (Figure 8). Current Lonestar operations are primarily in one large excavation (Figure 8 "Main Pit"), with processing in an adjacent plant which is located on original (unmined) ground adjacent to Calaveras Road.

Reclamation Plans

In terms of reclamation, the Santa Clara lease is somewhat specific in that, of 278 total acres (117 acres mined), 92 acres will be reclaimed to agriculture, 101 acres to future water storage, 45 acres to Alameda Creek, and approximately 40 acres to "planting areas, dikes,

etc.". The Mission Valley lease is less specific in that it adopts whatever reclamation provisions are included in the mining permits to be obtained by Mission Valley from Alameda County. Mission Valley has indicated that those provisions are to leave the excavations for water storage. Currently available water storage space in open excavations, excluding all area already backfilled (reclaimed) with fines, is approximately 12,000 acre-feet south of Interstate 680 and east of Alameda Creek (8,600 acre-feet on Santa Clara/Lonestar lease and 3,500 acre-feet on Mission Valley lease). In addition, there are about 3,500 acre-feet of storage adjacent to the Mission Valley plant west of the creek; that area is planned for ultimate reclamation to grade via deposition of process fines.

In light of the lack of significant potential well yields from the Livermore Gravels and the apparent low infiltration capacity into that formation, as discussed above, it is unlikely that a successful surface and ground-water conjunctive use operation could be implemented in the valley. As a result, in terms of water resource potential, sand and gravel excavation and subsequent reclamation for water storage appear to be compatible and generally consistent with City objectives. In terms of consistency between mining plans and water resource potential, there are several minor limitations: there are many subdivisions (individual, smaller excavations) not currently planned to maximize water storage volume; some of the excavations east of the creek, primarily in the Santa Clara/Lonestar lease, have been or are planned for sediment deposition, thus reducing potential water storage space; and there has heretofore been no continuity or planning among the City and the quarry operators to maximize water storage space after mining. An initial attempt to develop such consistency and maximize water storage space was undertaken in this study via definition of several mining plan alternatives for the valley.

Mining Alternatives

Mining alternatives in the Sunol Valley could range from the relatively small area currently mined to expanded mining of the valley floor, both in the currently mined area (between Interstate 680 and the Hetch-Hetchy Aqueduct crossing of the valley) and in areas north of

Interstate 680 as well as south of the Hetch-Hetchy crossing. For purposes of evaluation relative to water resources in the valley, that range has been organized into the following four mining alternatives: 1) continue and complete existing permitted mining; 2) extend depth of existing mining; 3) expand mining areas north and south of Interstate 680; and 4) expand mining to the area south of the Hetch-Hetchy crossing.

Complete Existing Permitted Mining - This alternative, illustrated in Figure 9, would primarily involve mining between Interstate 680 and the Hetch-Hetchy crossing to the south, plus the currently leased and permitted 70 acre "Vineyard Lease" immediately north of Interstate 680. Lonestar's operations, currently scheduled to be completed and reclaimed by the end of the lease in the year 2000, would involve its "Main Pit" and a second smaller excavation, both mined to 140 feet. Two or three smaller excavations would also be completed between the larger pits; and the recently leased and permitted 45 acres adjacent to the plant on Calaveras Road would be mined but reclaimed back to grade with fines from the Lonestar processing plant. Mission Valley's operations would involve completion of mining in the "New Lease" area, immediately south of Interstate 680, and expansion of mining to the 70 acre "Vineyard Lease" immediately north of Interstate 680; all those excavations would be to a depth of 140 feet.

Extend Depth of Existing Mining - This alternative is identical to the previous alternative in terms of surface area mined; the only difference would be extension of mining to a depth of 200 feet rather than the currently leased and permitted 140 feet (Figure 10). The 200 foot depth horizon has been suggested by the quarry operators for extension of existing mining primarily because it increases their aggregate reserves, and also because they have recognized the lack of ground-water related impacts, i.e. as discussed above in this report, shallow ground water from the alluvium can be controlled via cutoff walls or drainage, and deep ground water in the Livermore is either not present (unsaturated immediately below the alluvium) or seeps at sufficiently low rate to not impact dry pit mining. Given the areal extent of the various existing pits, and considering the practical impacts of sidewall slopes associated with excavations (specified to be no steeper than 2:1 in the lease agreements), a

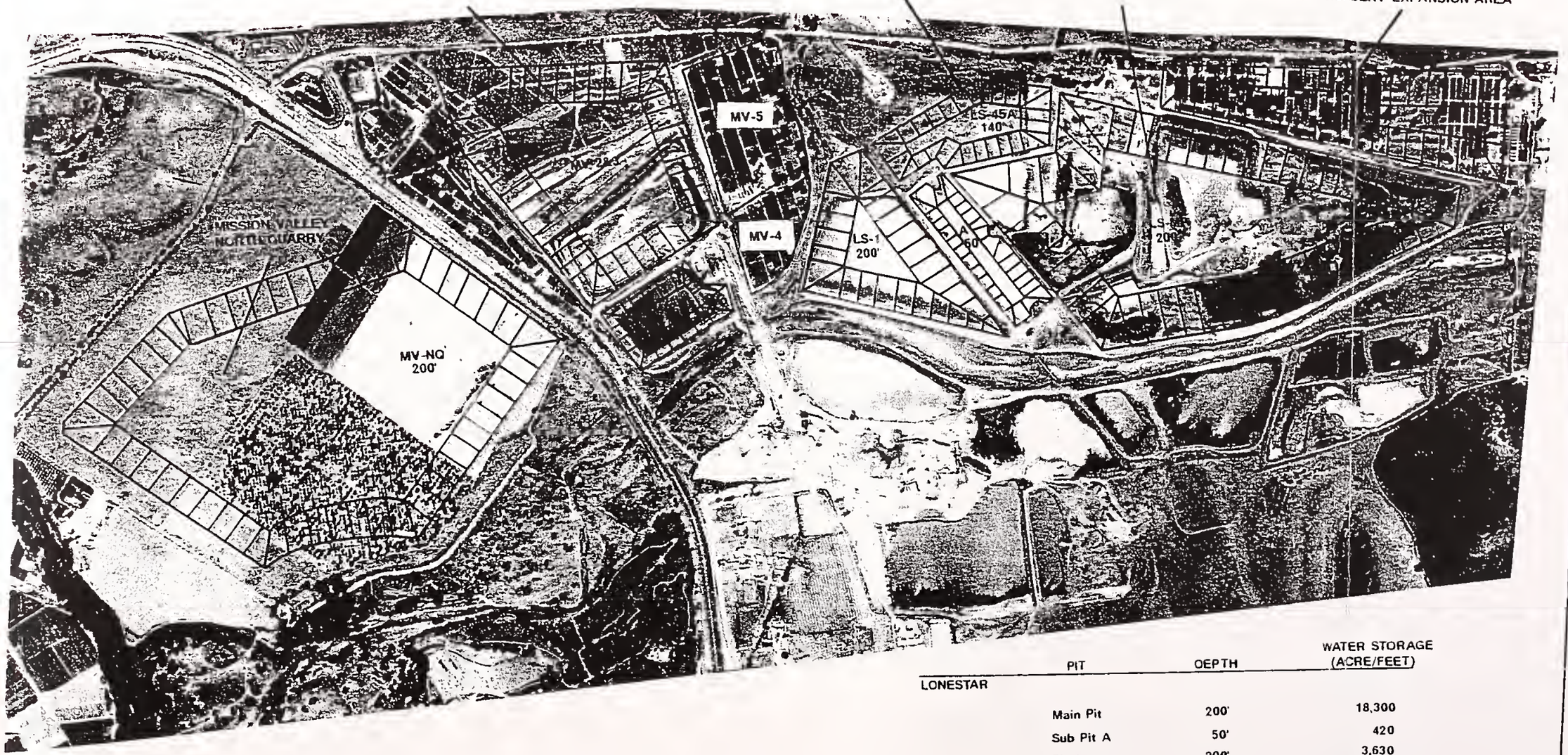
200 foot mining depth represents a likely limit to mining depth where the larger pits will still have some floor area. It is unlikely that mining could practically extend much deeper in any but the two largest existing pits without significant steepening of the side slopes, a potential concern both in terms of lease provisions and, more importantly, side slope stability.

Expand Existing Mining Areas - In this alternative, the primary mining area between Interstate 680 and the Hetch-Hetch crossing would be expanded to certain, more "fixed" boundaries (Figure 11). The nursery area east of the Lonestar Main Pit, and the Lonestar plant site could be mined; the Christmas tree nursery east of the Mission Valley "New Lease" could also be mined. Arbitrarily, for this study, the nursery operation adjacent to Interstate 680 was not added to the potentially mined area, but was left as a buffer between the freeway and the mining operations. Also, rights-of-way for major infrastructure facilities were excluded from potential expanded mining; those include the State Water Project's South Bay Aqueduct, PG&E and Hetch-Hetchy power line crossings, a PG&E high pressure natural gas transmission mainline, and the San Francisco pipeline between San Antonio Reservoir and the Sunol Filter Plant.

Also in this alternative, the mining area north of Interstate 680 would be expanded across much of the total 240 acre parcel between the freeway and the Water Temple, and between Calaveras Road and Alameda Creek. The potentially mined area would be limited, as illustrated in Figure 11, to preserve an identified archaeological site near the Water Temple and to allow mitigation of agricultural impacts by relocating (replacing) the existing vineyard and/or walnut orchard to near Interstate 680 and Calaveras Road.

Assuming that the above alternatives precede this alternative in some ultimate sequence of mining alternatives, the mining depth in the previous alternative would already be 200 feet. Consequently, this alternative would include mining to 200 feet.

Expand Mining to South of Hetch-Hetchy - There has apparently been little, if any, consideration ever given to the possibility of this mining alternative. However, although the



PIT		DEPTH	WATER STORAGE (ACRE/FEET)
LONESTAR			
	Main Pit	200'	18,300
	Sub Pit A	50'	420
	Pit 1	200'	3,630
	45 Acre Lease	140'	2,000
		Lonestar Total	24,350
NURSERY EXPANSION AREA			
	100' Area	100'	940
	200' Area	200'	2,640
		Nursery Area Total	3,580
MISSION VALLEY			
	Pit 1	200'	1,560
	Pit 2 & 3 & XMas Tree	200'	12,060
	Pit 4	200'	700
	Pit 5	200'	2,500
		New Lease Total	16,820
MISSION VALLEY NORTH QUARRY			
	MV-NQ	200'	23,470
		Mission Valley Total	40,290
		Option D Total	68,220

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AGGREGATE PIT
ACTIVE OR COMPLETE

FORMER AGGREGATE PIT
USED FOR SEDIMENTATION
BASIN - FILLED WITH
CLAYS & SILTS

FIGURE 11

Expansion of Existing
Mining Areas
Sunol Valley/Alameda Creek Leases

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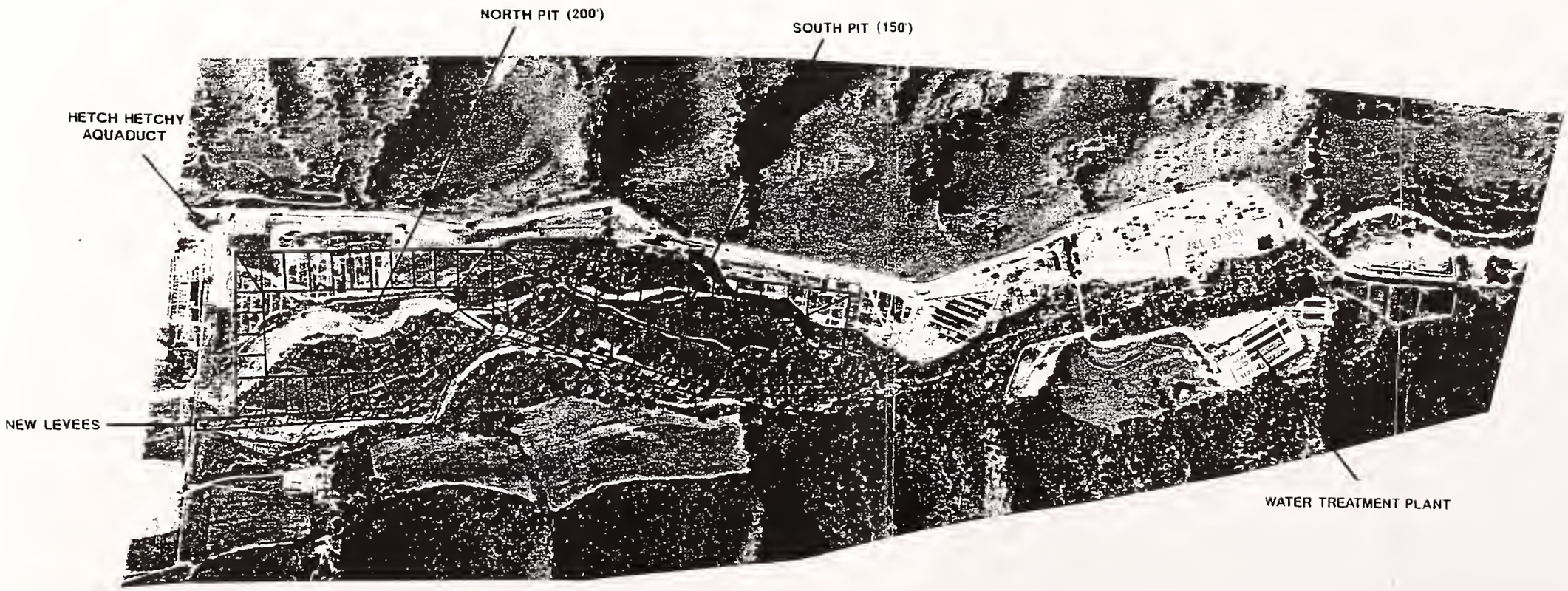
valley narrows to the south and would thus ultimately limit mining depths due to sidewall slope constraints, there are both shallow alluvium and underlying Livermore Gravels in that area which could be mined, with the excavations reclaimed for water storage. A two-pit configuration of possible expanded mining to this area in illustration Figure 12.

Quarry Management

The development of a complete quarry management plan for the Sunol Valley would not be appropriate if it were to be based entirely on the findings and analyses of this ground-water component of the overall water resources planning investigation of the Alameda Creek watershed. However, it is possible to develop an approach toward quarry management that focuses on potential water resource development and recognizes the constraints to potential conjunctive use of surface and ground water in the valley.

As developed in the discussions of aquifer characteristics and potential well yields above, it is unlikely that a conjunctive use program could be effectively implemented due to physical limitations to both recharge (infiltration) of water into the Livermore Gravels and extraction of water at reasonable capacities from wells completed in that formation. Consequently, from a water resources standpoint alone, the valley in a natural state is a very limited water resource. Increasing water resource potential would require an addition of storage capacity; lacking ground water as a potential component of additional storage, increased storage capacity then equates to increased surface reservoir volume. In that light, the following approach to quarry management has been developed to incorporate some consistencies among overall quarry operations and reclamation, with the intent to maximize surface water storage. It should be recognized that "maximum" surface water storage would result from completion of all the mining alternatives described above; however, maximum desired or required surface water storage may be constrained by other considerations independent of this analysis, i.e. land use preferences, reservoir operations considerations, etc. Since reservoir operations considerations are another part of the current overall Alameda Creek investigation, no attempt was made to incorporate them in this part of a quarry management



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AGGREGATE PIT
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FORMER AGGREGATE PIT
USED FOR SEDIMENTATION
BASIN - FILLED WITH
CLAYS & SILTS

	PIT	DEPTH	WATER STORAGE (ACRE/FEET)
EXPANSION AREA			
	North Pit	200'	6,650
	South Pit	150'	4,580
			Total 11,230

Expansion of Existing Mining
Addition of Area South of
Hetch Hetchy
Sunol Valley/Alameda Creek Leases

Sunol Valley Ground-Water & Aggregate Resources

FIGURE
12

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plan.

Lease Provisions - Generally introduced above in the discussion of current mining, San Francisco has two leases for ongoing surface mining of sand and gravel. One lease continues in effect with the original lessee (Santa Clara Sand and Gravel) and the parent company (RMC Lonestar) which apparently acquired it since the effective date of the lease. The other lease has been sublet or assigned to the current quarry operator, Mission Valley Rock.

The first quarry lease is between San Francisco and Santa Clara Sand and Gravel, dated December 31, 1980; it continues for a period of 20 years. Included in the lease are a total of 278 acres, of which 117 acres are to be mined and the total area reclaimed as follows: 92 acres of agricultural area, 101 acres of water storage, 45 acres for Alameda Creek alignment, and approximately 40 acres for "planting areas, dikes, etc." The original lease limited mining depth to 100 feet; a first supplemental agreement in 1986 increased the mining depth to 140 feet. The first supplemental agreement also increased royalty from the original $0.30 per ton of aggregate products ($125,000 annual minimum royalty) to $0.50 per ton ($200,00 annual minimum royalty), subject to annual adjustments based on percentage changes in the San Francisco Construction Cost Index. A 1993 lease amendment added 45 acres to the mined area, immediately north of the plant site, for quarrying, deposition of fines from processing, and reclamation to agriculture.

The second quarry lease is between San Francisco and Armanino Farms, dated June 20, 1985; it continues through October 31, 2012. Included in this lease are 204 acres immediately north (69 acres) and south (135 acres) of Interstate 680. The southern 135 acres were originally sublet to Mission Valley Rock on June 20, 1985; the entire 204 acre lease was subsequently assigned to Mission Valley Rock in December, 1986. All the area is leased to be mined; reclamation is to be in accordance with provisions in the surface mining permit issued by Alameda County. Current plans are to reclaim the excavations for water storage. The original lease limited mining depth to 100 feet; a second supplemental

agreement increased the mining depth to 140 feet. Royalty provisions are $0.50 per ton of aggregate products, but not less than $1,000,000 over the term of the lease. The royalty provisions were subject to review and adjustment in January, 1988 and every five years thereafter. No adjustment index is specified; it is merely stated that "any increase of royalty payment to City shall be justifiable and fair". Mission Valley Rock commented during this investigation that its royalty is now $0.60 per ton; however, since there were no lease documents to that effect, the royalty calculations herein were based on the same lease royalty rate for both operations, $0.50 per ton. Of course, a royalty rate increase such as $0.10 per ton represents a 20 percent increase and would notably impact the revenue from mining as discussed below.

Potential Reservoir Storage Space - At present, there are approximately 12,000 acre-feet of potential reservoir storage space in the open excavations being operated by Lonestar and Mission Valley Rock east of Alameda Creek between Interstate 680 and the Hetch-Hetchy crossing (Figure 8). Completion of currently leased and permitted mining to 140 feet (except where constrained by sidewall slopes) will enlarge that potential reservoir storage space to 31,000 acre-feet as follows: 16,000 acre-feet on the Santa Clara/ Lonestar lease; 11,000 acre-feet on the Armanino/Mission Valley "New Lease" south of Interstate 680, and 4,000 acre-feet on the same operator's "Vineyard Lease" north of Interstate 680 (Figure 9). Extension of mining within the currently leased and permitted area to 200 feet (except where constrained by sidewall slopes) will further enlarge potential reservoir storage space to 40,000 acre-feet as follow: 19,000 acre-feet on the Santa Clara/Lonestar lease; 13,000 acre-feet and nearly 8,000 acre-feet on the Armanino/Mission Valley "New Lease" and "Vineyard Lease" respectively.

Expansion of the currently leased areas to more fixed boundaries, with appropriate reservations for major infrastructure facilities and mitigation features as described above, could yield another increment of potential reservoir storage. If mining over that area (Figure 10) is uniformly to 200 feet (except where constrained by sidewall slopes), total potential reservoir storage would be 68,000 acre-feet as follows: 28,000 acre-feet on the

current Santa Clara/Lonestar leases, including the plant site and the adjoining nursery expansion area; 17,000 acre-feet on the current Armanino/Mission Valley "New Lease" and the adjoining Christmas tree expansion area; and 23,000 acre-feet on an expanded Armanino/Mission Valley "Vineyard Lease" north of Interstate 680.

Finally, if mining were extended south of Hetch Hetchy, it appears that two excavations could be mined and reclaimed to water storage: a northerly pit to 200 feet and a southerly narrow pit to about 150 feet. Completion of both those pits could add about 11,000 acre-feet of reservoir storage space to the valley.

Royalties and Revenue - Both current lease provisions specify a royalty payment of $0.50 per ton of sand and gravel products removed from the quarries on San Francisco property. There are minimum royalty payments also specified: $125,000 per year on the Santa Clara/Lonestar lease, and $1,000,000 over the term of the lease on the Armanino/Mission Valley lease. In terms of royalty income to San Francisco, the mining alternatives described herein represent a substantial revenue stream through 2000 on the Santa Clara/Lonestar lease, and through 2012 on the Armanino/Mission Valley lease.

The California Division of Mines and Geology, in estimating aggregate resources in the Bay Area, has used values of 138 lb./ft^3 for a gross density of sand and gravel materials, and 90 percent net salable products from the gross mined material. Based on those factors and the current royalty of $0.50 per ton, the royalty income to San Francisco for mining to date has been about $16,400,000 (Table 4). Adoption of the mining alternatives described therein would increase that royalty income notably (Table 4), even if no adjustment to the $0.50 per ton royalty is ever made. Completion of the existing leased and permitted mining would bring royalty income to a total of $44,600,000; it would also produce about 31,000 acre-feet of potential reservoir storage. Extension of mining depth to 200 feet on the currently leased area would increase royalty income by $12,300,000, to a total of $56,900,000 while also increasing potential reservoir storage to 40,000 acre-feet. Expansion of mined area both north and south of Interstate 680 would notably increase royalty income to about

Table 4

Aggregate Mining Royalties[1]
Sunol Valley/Alameda Creek Leases

Lease/Mined Area	Existing Mining (to date)	Complete Mining on Existing Leases	Extend Mining to 200 ft. Existing Leases	Mining Expansion on/around Existing Leases	Mining Expansion South of Hetch Hetchy
Santa Clara Sand & Gravel (RMC Lonestar)	$ 11,600,000	$ 12,800,000	$ 4,500,000	$ 4,000,000	
Mission Valley Rock					
New Lease	4,800,000	9,800,000	3,100,000		
Vineyard Lease		5,600,000	4,700,000		
North Quarry				21,500,000	
Nursery Area				4,800,000	
Christmas Tree Farm				5,100,000	
Valley Floor South					$ 15,200,000
Subtotal	$ 16,400,000	$ 28,200,000	$ 12,300,000	$ 35,400,000	$ 15,200,000
Cumulative Total	$ 16,400,000	$ 44,600,000	$ 56,900,000	$ 92,300,000	$ 107,500,000

1. based on current royalty rate of $0.50 per ton of aggregate products, gross density of 138 lb./ft^3, and 10% waste

$92,300,000 while producing 68,000 acre-feet of potential reservoir storage space. Finally, expansion of mining to the area south of the Hetch Hetchy crossing would add about $15,000,000 in royalty income while adding about 11,000 acre-feet of potential reservoir space.

Simply summarized, San Francisco can increase its surface reservoir space significantly: to 31,000 acre-feet by completing current mining leases and permits; and into the range of 40,000 to 80,000 acre-feet by allowing extension (to 200 feet) and/or expansion (north and south of Interstate 680, including south of the Hetch Hetchty crossing) of currently mined areas. Completion of current mining leases and permits will result in a total royalty income of $44,600,000. Extension and/or expansion of mining as described herein would generate total royalty income in the range of $57,000,000 to nearly $108,000,000.

Other Considerations - As briefly noted above, there are two considerations which have not been historically addressed by the City and its lessees relative to maximizing surface reservoir storage space from the gravel quarries: there has been no integrated plan toward reclamation and use of the space for reservoir storage, with appropriate recognition of existing infrastructure and its impact on an overall reservoir system; and there has been no consistent plan toward deposition of fines from gravel processing that will allow maximum reservoir storage space. With regard to the former, the mining alternatives described herein can allow the City to follow a selected course toward mining which will result in an end storage volume of about 30,000 acre-feet at the completion of currently leased and permitted mining, up to nearly 80,000 acre-feet if all possible mining is undertaken and completed. The ultimate size of reservoir volume can be selected on factors such as useful storage in the overall system, land use desires in the valley, and economic income associated with reservoir "construction", i.e. royalty payments by the lessees as they excavate the ultimate reservoir space.

With regard to disposal of fines from gravel processing, it is advantageous to the City that Mission Valley removes all mined material from its leases for processing west of Alameda

Creek. In that regard, the potential reservoir space is the result of gross mining; fines are deposited near the plant site and the "net" excavation is not reduced by return of fines. On the other hand, Lonestar deposits fines in former quarry excavations near its plant site which is east of the creek. The primary motivation for the recent 45 acre addition to its lease was to provide additional space for deposition of fines, hence the plan to reclaim it to its original surface and dedicate it to agriculture. Obviously, any operational change that could incorporate removal of fines from the mined area would add to the net available reservoir storage volume.

Finally, although not a specific part of the scope of this investigation, it is recognized that the excavations extend over a limited area of the valley, and could extend over a much longer area, that declines in surface elevation from south to north. Hence, depending on the ultimate selection of mined area and reservoir configuration, future attention will be required to develop an operational plan for filling and draining a series of reservoirs at different elevations. One obvious consideration in such a plan will be the fact that such reservoirs will be at the lowest elevations in the overall San Francisco system, and will thus require the most energy (pumping) to be introduced to the water supply system, presumably via the Sunol Filter Plant.

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APPENDIX H

REPORT ON
WATER RECOVERY FACILITIES
JUNE 1994

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SECTION 1 INTRODUCTION

STUDY BACKGROUND

The San Francisco Water Department (SFWD) retained Bookman-Edmonston Engineering, Inc. (B-E) in August 1992 to investigate the potential for improved water resource utilization in the Alameda Creek Watershed. As part of that investigation, B-E was to assess riparian conditions in the watershed on portions of Calaveras Creek and Alameda Creek below Calaveras Reservoir and to determine the feasibility of establishing a trout fishery in that area utilizing flows released from Calaveras Reservoir. If establishment of a trout fishery utilizing flows from Calaveras Reservoir proved feasible, B-E was to identify engineering alternatives for recapturing these flows for return to SFWD's water transmission system.

B-E subcontracted the assessment of riparian conditions to Ogden Environmental and Energy Services Co., Inc. (Ogden) and the assessment of the feasibility of establishing a trout fishery to BioSystems Analysis, Inc. (BioSystems). Ogden concluded in its report, *Alameda Creek Revegetation/Restoration Report* (May 1993), that riparian conditions in Calaveras Creek and Alameda Creek below Calaveras Reservoir were conducive to establishment of a trout fishery. Likewise, BioSystems concluded in its report, *Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan* (February 1993), that establishment of a trout fishery was feasible and made recommendations on the timing and volume of flow releases from Calaveras Reservoir required to support such a fishery.

At the request of the SFWD, Dr. Peter Moyle from the University of California at Davis reviewed the flow release program recommended by BioSystems. Dr. Moyle stated that, in his opinion, the trout fishery restoration effort recommended by BioSystems could result in the decline in the population of native nongame fish in Alameda Creek. Thus, BioSystems amended their initial report to identify a flow release program that would permit establishment of a trout fishery without negatively impacting the native nongame fishery (see *Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan–Final Report*, November 1993). An operations model of the Alameda Creek Watershed developed by B-E (see *Alameda Creek Watershed Study, Report on Watershed Operations*, Bookman-Edmonston Engineering, Inc., January 1994) confirmed the availability of requisite flows for support of the fishery.

Representatives from the California Department of Fish and Game (DFG) and the public interest group, CalTrout, were kept apprised throughout the riparian condition and fishery release investigations. DFG and CalTrout were given the opportunity to review and comment on the findings and recommendations of both studies.

DESCRIPTION OF PROJECT AREA

Figure 1 shows the principal features of the Alameda Creek Watershed. Of particular interest in this report is the area below Calaveras Reservoir known as the Sunol Valley. Portions of Calaveras Creek and Alameda Creek between Calaveras Reservoir and the Sunol Valley Filtration Plant (filtration plant) have been identified as suitable locations for establishment of a trout fishery. Potential sites for the flow recapture facilities have been identified downstream of the filtration plant within the Sunol Valley.

The SFWD has developed extensive water storage, treatment, and distribution facilities within the Sunol Valley (see Figure 2). Calaveras Reservoir, which has a capacity of 96,000 acre-feet, impounds drainage from the Calaveras Watershed and diversions from the Upper Alameda Watershed diverted via the Alameda Creek Diversion Dam and Tunnel. San Antonio Reservoir, which has a capacity of 58,000 acre-feet, impounds drainage from the San Antonio Watershed and diversions from both the Hetch Hetchy Aqueduct and Calaveras Reservoir. During the most recent drought, water was delivered to San Antonio Reservoir from the South Bay Aqueduct. Water from Calaveras Reservoir and San Antonio Reservoir can be delivered to the filtration plant for treatment and subsequent delivery to SFWD service areas via the Hetch Hetchy Aqueduct. The San Antonio Pumping Plant, centrally located within the Sunol Valley, is utilized to distribute water between the filtration plant, the Hetch Hetchy Aqueduct, and San Antonio Reservoir. Water from Calaveras Reservoir can be delivered by gravity to the filtration plant, the Hetch Hetchy Aqueduct, or San Antonio Reservoir.

At the downstream end of the Sunol Valley, SFWD operates the Sunol Infiltration Gallery, which consists of subsurface vaults which intercept groundwater flow. Water collected in the infiltration gallery flows through the Sunol Water Temple to the Sunol Pumping Plant, which pumps the water to San Antonio Reservoir for temporary storage or to the filtration plant for treatment. The importance of the Sunol Infiltration Gallery has diminished over time as a result of the development of upstream storage capability at San Antonio and Calaveras Reservoirs.

In the central portion of the Sunol Valley are gravel quarry operations conducted on lands leased by SFWD to quarry operators. Quarry operations have impacted subsurface flows to the Sunol Infiltration Gallery through the interception of groundwater flows.

IDENTIFICATION OF FLOW RECAPTURE ALTERNATIVES

It was originally thought that flows released from Calaveras Reservoir to support establishment of a trout fishery could be recaptured at the Sunol Infiltration Gallery. The

FIGURE

PLEASANTON
LAKE DEL VALLE
SAN ANTONIO WATERSHED
SAN ANTONIO RESERVOIR
SUNOL
SUNOL WATER TEMPLE
SUNOL VALLEY
NILES CANYON
SUNOL VALLEY FILTRATION PLANT
LOWER ALAMEDA WATERSHED
ALAMEDA CREEK DIVERSION DAM
ALAMEDA SANTA CLARA CO. CO.
UPPER ALAMEDA WATERSHED
STANISLAUS SANTA CLARA CO. CO.
SCALE: 1" = 12000'
CALAVERAS RESERVOIR
CALAVERAS WATERSHED
FREMONT
MILPITAS
SUNNYVALE
SAN JOSE

LEGEND
- PIPELINE/AQUEDUCT
- WATERSHED BOUNDARIES
- STREAM
- PAVED ROAD
- HIGHWAY

ALAMEDA CREEK WATER RESOURCES STUDY

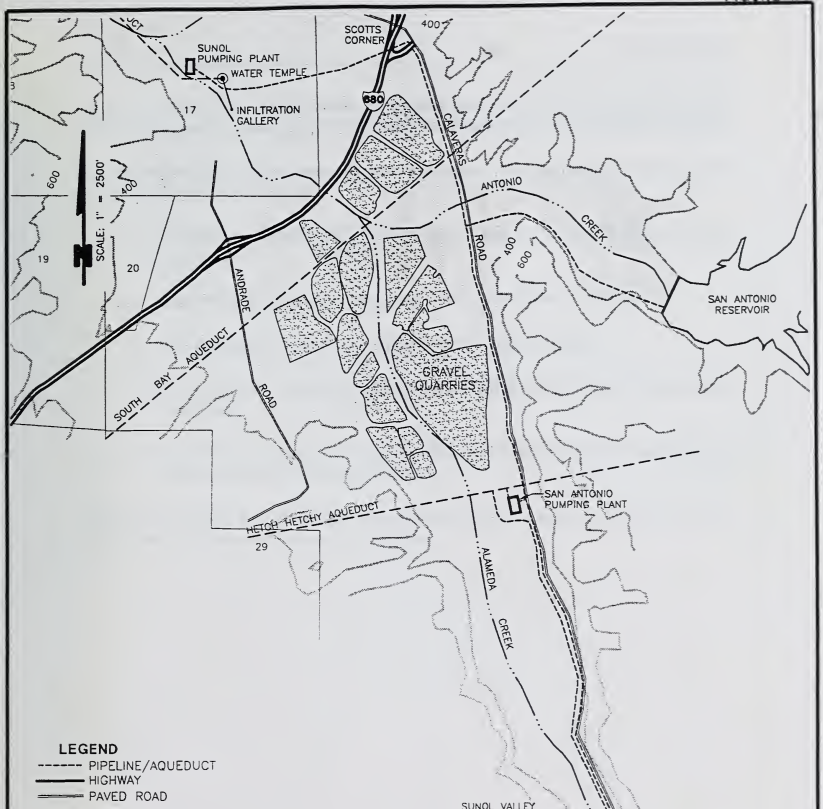
PROJECT AREA

SAN FRANCISCO WATER DEPARTMENT

BOOKMAN–EDMONSTON ENGINEERING, INC.

APRIL 1994

FIGURE 2



ALAMEDA CREEK WATER RESOURCES STUDY

LOCATION MAP OF SUNOL VALLEY FACILITIES

SAN FRANCISCO WATER DEPARTMENT

/DWG/04445/QL004 4/14/94

age and condition of the facility, however, coupled with the impact of the gravel quarries in the central portion of the Sunol Valley, limit the effectiveness of the infiltration gallery.

This report identifes and evaluates a number of alternatives for recapturing these flows in an efficient and effective manner:

- Utilization of abandoned gravel quarries within in the Sunol Valley as storage reservoirs.
- Rehabilitation and improvement of the Sunol Infiltration Gallery.
- Development of conjunctive operations in the Sunol Valley.
- Development of a dense, shallow well field in the Sunol Valley for subsurface recapture.
- Installation of an inflatable rubber dam in the Alameda Creek streambed for surface impoundment and recapture.

Addtionally, facilities and operational procedures required to return recaptured flows to SFWD's water transmission system are identified.

SECTION 2 REQUIREMENTS FOR RECAPTURE FACILITIES

Three principal factors affect the design of facilities for recapturing flow releases from Calaveras Reservoir into Alameda Creek: the nominal capacity for which the facilities should be designed; the disposition subsequent to recapture (that is, to where should the recaptured flows be delivered); and the location at which the recapture facilities should be constructed to ensure their effectiveness.

RECAPTURE CAPACITY REQUIREMENTS

The required capacity of the recapture facilities is primarily dependent upon the flow release schedule from Calaveras Reservoir. The timing and magnitude of local runoff and spills from the Alameda Creek Diversion Dam are of secondary importance.

Table 1 provides a summary of the flow release schedule recommended by BioSystems which will permit the establishment of suitable trout habitat in Alameda Creek downstream of Calaveras Reservoir without negatively impacting the native nongame fishery (see *Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan, Final Report*, November 1993).

Table 1
RECOMMENDED FLOW RELEASES FROM CALAVERAS RESERVOIR FOR ESTABLISHMENT OF SUITABLE TROUT HABITAT IN ALAMEDA CREEK[1]

Month	Recommended Flow[2] (cfs)	Total Volume Released (acre-feet)
January	5	307
February	20	1,112
March	20	1,230
April	7	416
May	7	430
June	7	416
July	7	430
August	7	430
September	7	416
October	7	430
November	5	298
December	5	307
Total	—	6,222

[1] Source: Report prepared by BioSystems Analysis, Inc. entitled *Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan, Final Plan*, November 1993.

[2] Recommended flow is a five-day running average flow measured immediately downstream of the confluence of the Alameda and Calaveras Creeks with a minimum mean daily flow of not less than 90 percent of the recommended flow.

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Table 1 indicates that the recapture facilities should be designed for a nominal capacity of 20 cubic feet per second (cfs). The opportunity exists, however, for capturing flows from local runoff and from spills at the Alameda Creek Diversion Dam that historically have been captured at the Sunol Infiltration Gallery with appropriately designed and constructed facilities. An operations model of the Alameda Creek Watershed developed by B-E determined that, in the long term, the availability of flows in Alameda Creek may justify increasing the capacity of the recapture facilities to about 50 cfs (see *Alameda Creek Watershed Study, Report on Watershed Operations*, Bookman-Edmonston Engineering, Inc., January 1994). Thus, for this report, alternatives for recapture facilities with the flexibility to recapture and deliver a range of flows up to 50 cfs were investigated.

DISPOSITION OF RECAPTURED WATER

Recaptured flows will be returned to SFWD's Sunol Valley facilities for either storage in the local reservoirs or for immediate treatment and delivery to SFWD service areas. The disposition of the recaptured flows is dependent upon the manner in which the SFWD Sunol Valley facilities are being operated at the time of recapture. The design of the recapture facilities must be compatible with each of the typical "operational modes" of the existing facilities.

Description of Existing Facilities

Figure 3 provides a schematic diagram of the existing Sunol Valley facilities.

The Hetch Hetchy Aqueduct serves as the principal conduit for delivering Hetch Hetchy water and water from the Alameda, Calaveras, and San Antonio watersheds to SFWD service areas. Flows in the aqueduct from Hetch Hetchy can be pumped into San Antonio Reservoir for storage via the San Antonio Pumping Plant (when San Antonio Reservoir storage levels are low, the aqueduct can deliver flows to San Antonio Reservoir by gravity); pumped to the filtration plant via the San Antonio Pumping Plant for treatment and return to the aqueduct for delivery to SFWD service areas; or passed directly through the Sunol Valley (because of its high quality, water from Hetch Hetchy often does not require treatment).

Runoff from the Calaveras Watershed is impounded in Calaveras Reservoir, as is runoff from a portion of Alameda Watershed diverted into Calaveras Reservoir by the Alameda Creek Diversion Dam. Water in Calaveras Reservoir can be delivered by gravity to the filtration plant for treatment and introduction into the Hetch Hetchy Aqueduct for delivery to SFWD service areas, or delivered by gravity to the San Antonio Reservoir. Water stored in San Antonio Reservoir must be pumped via the San Antonio Pumping Plant to the filtration plant for treatment before introduction into the Hetch Hetchy Aqueduct for delivery.

Water captured by the infiltration gallery at the Sunol Water Temple can be pumped by the Sunol Pumping Plant to San Antonio Reservoir for storage or to the suction side of the San Antonio Pumping Plant, which boosts it to the filtration plant for treatment and introduction into the Hetch Hetchy Aqueduct.

Operational Modes of Existing Facilities

The disposition of the recaptured flow will depend upon the manner in which the facilities are being operated at the time of recapture. Figure 4 illustrates the four principal "operational modes" affecting the disposition of recaptured water. The distinguishing factor between these operational modes is the status of the San Antonio Pumping Plant, specifically, the source and destination of water pumped by that pumping plant. The status of the San Antonio Pumping Plant and its effect on the system energy gradeline significantly impacts the disposition of water from the recapture facilities.

Under Operational Mode A (see Figure 4a), the San Antonio Pumping Plant pumps water from the San Antonio Reservoir to the filtration plant for treatment and subsequent delivery to the Hetch Hetchy Aqueduct. Under this mode of operation, the Sunol Pumping Plant pumps water collected at the infiltration gallery (when available) to the suction side of the San Antonio Pumping Plant. Additionally, water can be delivered by gravity from Calaveras Reservoir to the filtration plant for treatment.

Under Operational Mode B (see Figure 4b), the San Antonio Pumping Plant pumps water from the Hetch Hetchy Aqueduct to the filtration plant for treatment. This mode of operation primarily occurs in the early spring at which time "yellow water" (so termed because of the yellow tint the water takes on from pollen) from Hetch Hetchy must be treated before delivery. In this mode of operation, a portion of the flow is diverted from the Hetch Hetchy Aqueduct for treatment, then reintroduced into the Hetch Hetchy Aqueduct for delivery to SFWD's service area. Under this mode of operation, the Sunol Pumping Plant pumps water collected at the infiltration gallery to the San Antonio Reservoir for storage. Water from Calaveras Reservoir can be delivered by gravity to the filtration plant as required to augment supply.

Under Operational Mode C (see Figure 4c), the San Antonio Pumping Plant pumps from the Hetch Hetchy Aqueduct to the San Antonio Reservoir for storage. This occurs when there is a reduction in demand within the SFWD's service area or when the Hetch Hetchy system is spilling at its source. Water collected at the infiltration gallery is pumped by the Sunol Pumping Plant to the San Antonio Reservoir. Water from Calaveras Reservoir is delivered by gravity to San Antonio Reservoir under this mode of operation as required to draw down Calaveras Reservoir.

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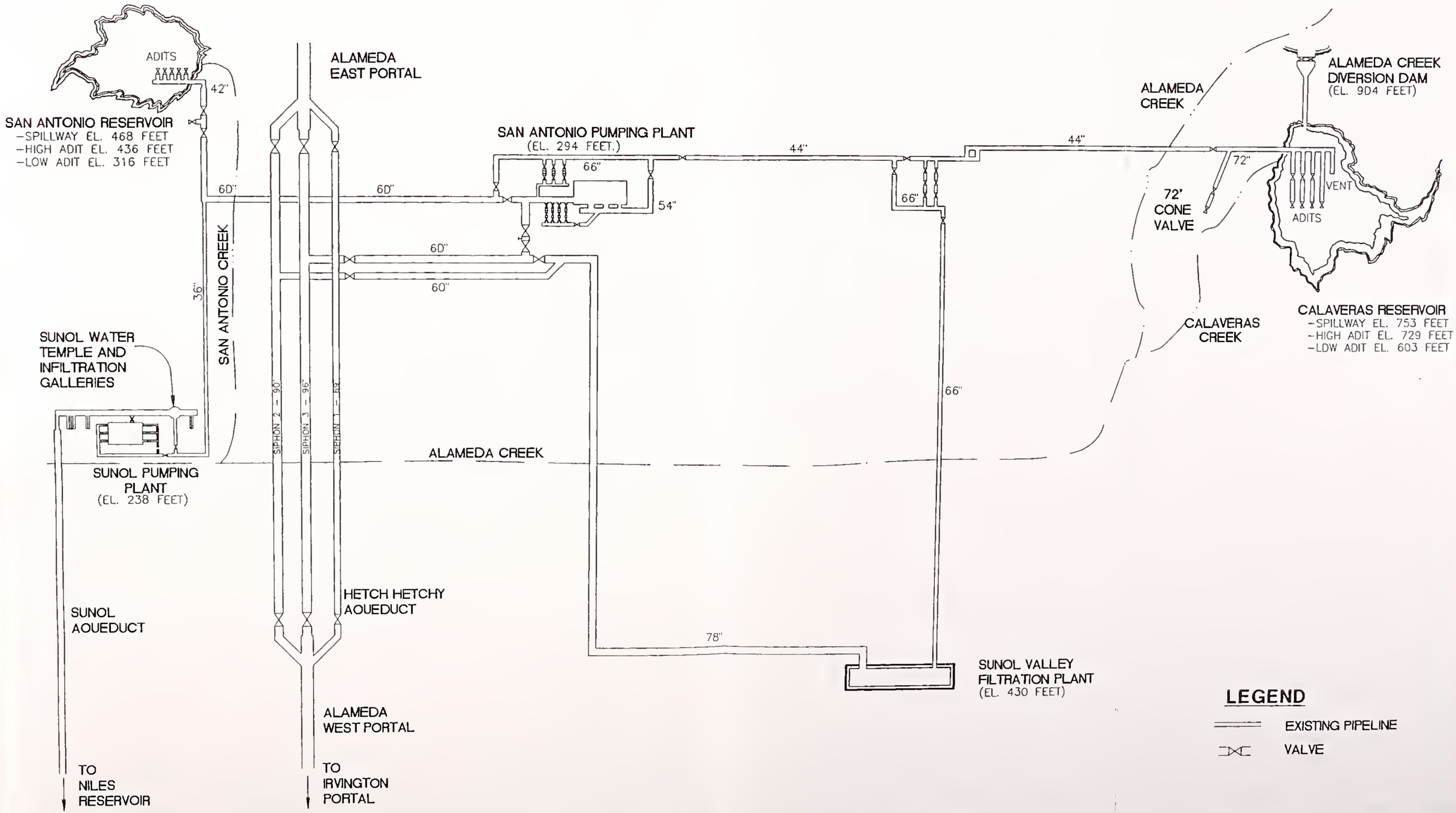
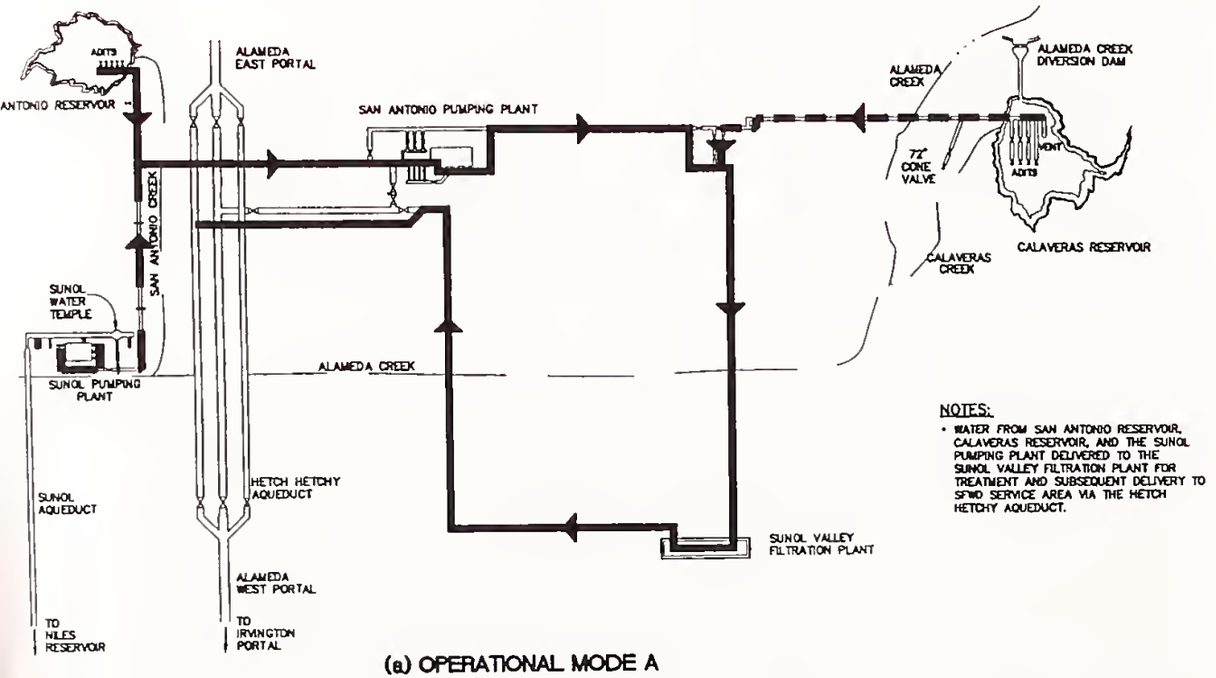


ALAMEDA CREEK WATER RESOURCES STUDY

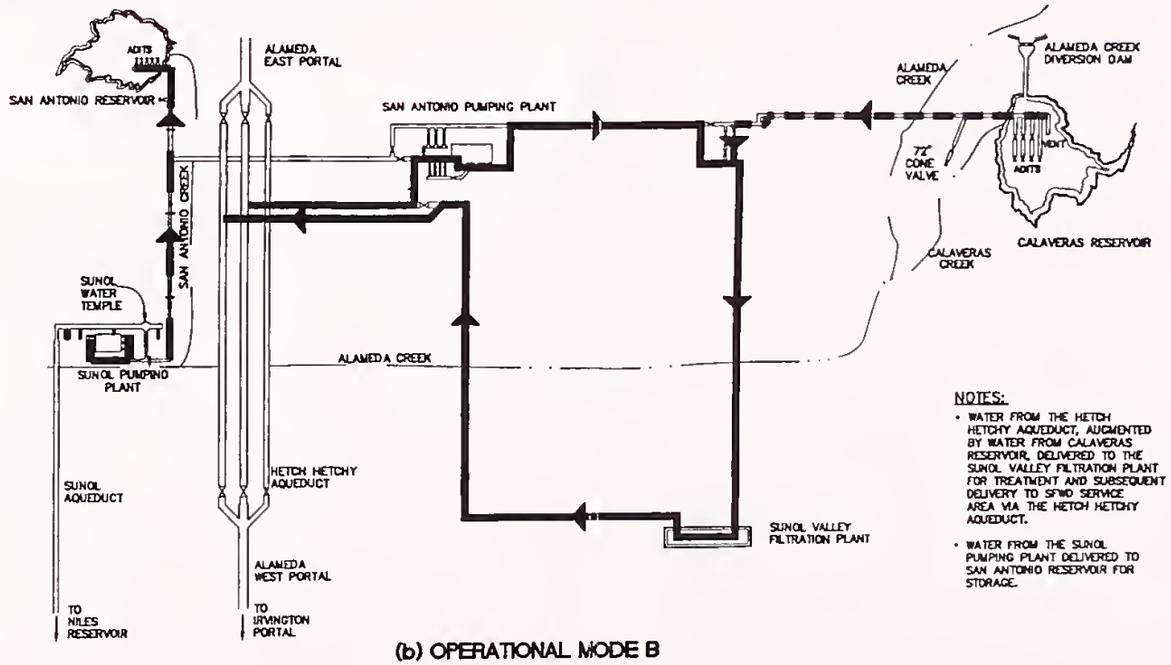
SYSTEM DIAGRAM OF SUNOL VALLEY FACILITIES

SAN FRANCISCO WATER DEPARTMENT

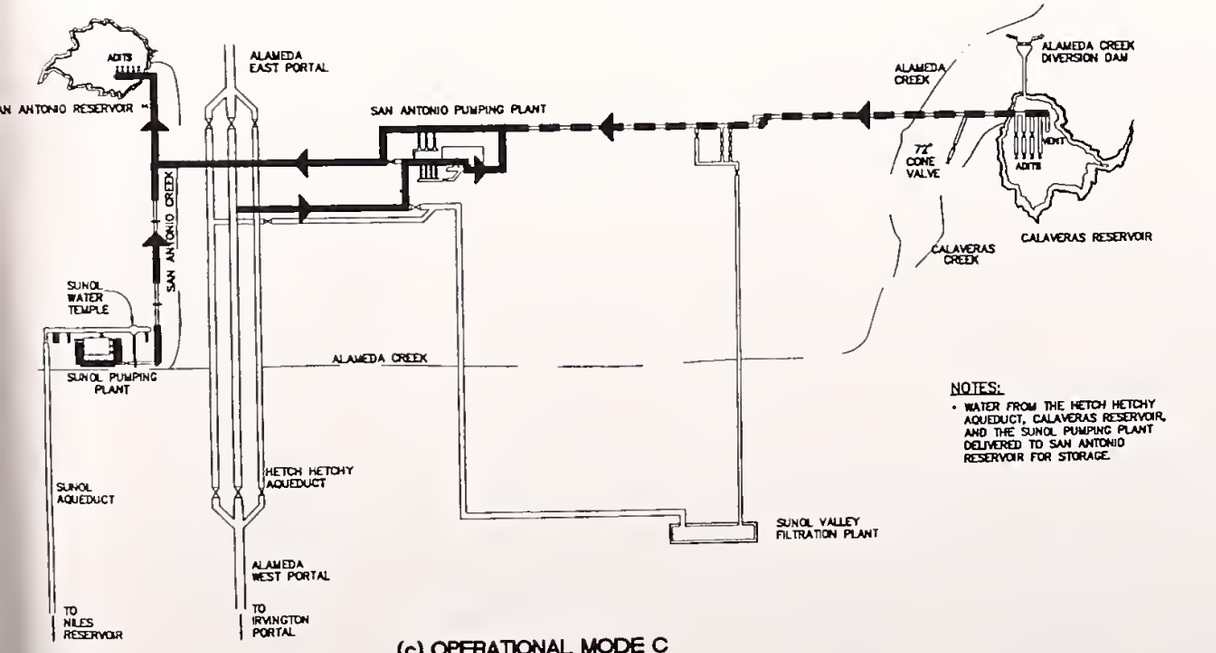
APRIL 1994



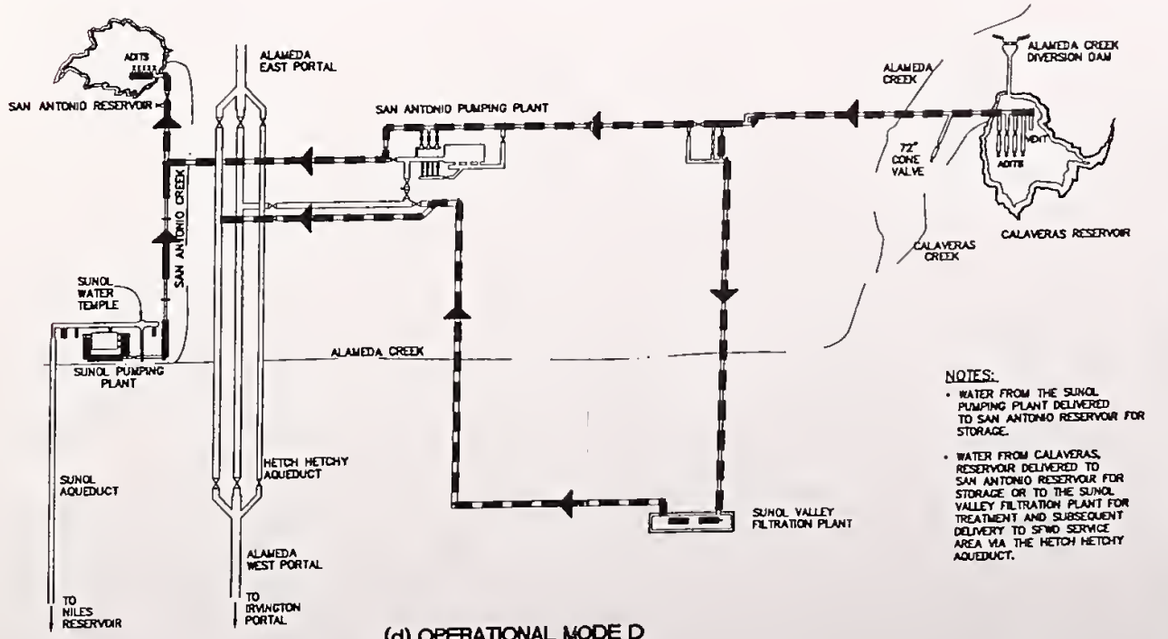
(a) OPERATIONAL MODE A



(b) OPERATIONAL MODE B



(c) OPERATIONAL MODE C



(d) OPERATIONAL MODE D

ALAMEDA CREEK WATER RESOURCES STUDY

OPERATIONAL MODES OF SUNOL VALLEY FACILITIES

SAN FRANCISCO WATER DEPARTMENT

Under Operational Mode D (see Figure 4d), the San Antonio Pumping Plant is not running. Water collected at the infiltration gallery is pumped by the Sunol Pumping Plant to San Antonio Reservoir for storage. Water from Calaveras Reservoir can be delivered by gravity to either the San Antonio Reservoir or to the filtration plant for treatment and delivery to SFWD's service area via the Hetch Hetchy Aqueduct.

Integration of Recapture Facilities with the Existing Facilities

Selection of the recapture facilities must consider both the existing facilities in the Sunol Valley and the potential long-term, or ultimate, configuration of the facilities. The existing system of distribution within the Sunol Valley should be utilized to the greatest extent practicable. Integration of the recapture facilities with the existing system depends primarily upon the disposition of water subsequent to recapture and the means and location of recapture.

Potential dispositions for recaptured flows include:

- Calaveras Reservoir
- Abandoned gravel quarries within the Sunol Valley
- San Antonio Reservoir
- The Sunol Valley Filtration Plant

Although returning the recaptured flows to Calaveras Reservoir is possible, as illustrated on Figure 5, the static lift required to return water to Calaveras Reservoir is considerable, potentially ranging from 300 to 450 feet (assuming flows are recaptured in Alameda Creek near the filtration plant). Given the limited opportunities for returning recaptured flows to Calaveras Reservoir (the single existing pipeline out of Calaveras Reservoir is often delivering water from the reservoir), sizing pumping facilities for that lift would not be practical.

Another alternative is to divert the flow releases into abandoned gravel quarries within the Sunol Valley. The gravel quarries, however, are not immediately available for use, and their availability will be incremental over an extended period of time (see *Groundwater and Aggregate Resources, Sunol Valley*, Luhdorff and Scalmanini, December 1993).

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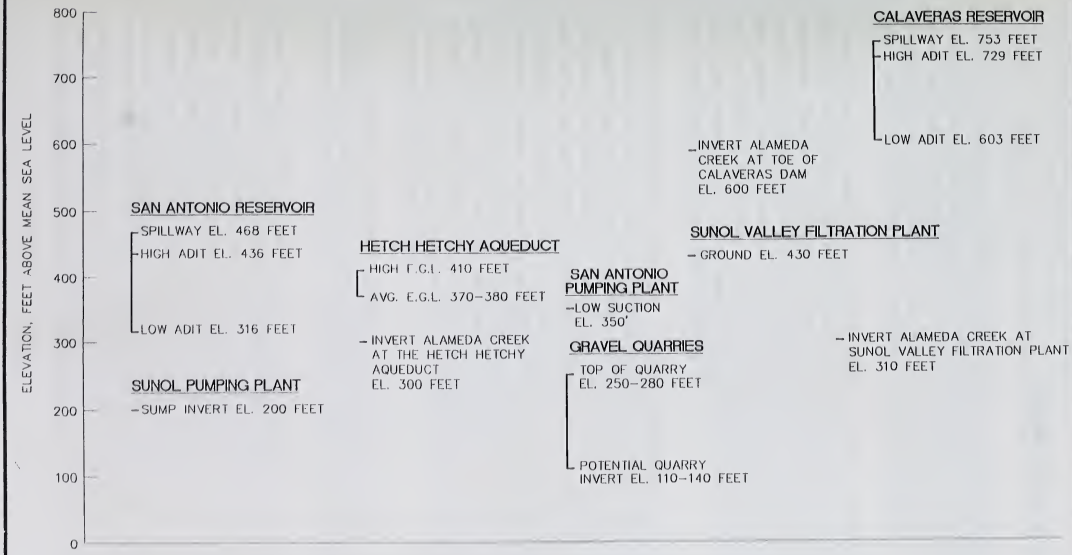

ALAMEDA CREEK WATER RESOURCES STUDY

ELEVATIONS OF ELEMENTS OF SUNOL VALLEY FACILITIES

SAN FRANCISCO WATER DEPARTMENT

DWG 0445 REVISE 4/20/84

In the short term, ongoing quarrying operations restrict the temporary use of the quarries as recapture sites. Quarrying operations would not only interfere with recapture efforts, but would also most likely negatively impact the quality of water recaptured. Thus, although the gravel quarries may ultimately be available for use as storage reservoirs, in the interim, they cannot be considered as viable elements of the recapture facilities.

The only practical options regarding the disposition of the recaptured flows, therefore, are delivering the flows to San Antonio Reservoir for storage or to the filtration plant for treatment. In either case, if possible, the San Antonio Pumping Plant should be utilized to provide the required lift for pumping recaptured flows. If it is not possible to utilize the San Antonio Pumping Plant, the recapture facilities must be provided with moderately high lift capabilities. In most cases, the preferred disposition of the water will be the filtration plant rather than the San Antonio Reservoir because of the lower required lift, particularly after accounting for dynamic losses (see Figure 5).

As previously discussed, one alternative is to utilize the existing Sunol Infiltration Gallery to recapture the flows. If the infiltration gallery at the Sunol Water Temple is maintained or rehabilitated, then the disposition of the water recaptured at the infiltration gallery is as previously described relative to the operation of the Sunol Pumping Plant. The other alternatives that have been identified require the construction of additional facilities and an examination of the operational procedures required to introduce the recaptured flows into the existing system. As illustrated on Figure 5, however, the infiltration gallery is the lowest point hydraulically in the entire Sunol Valley (only the inverts of the potential abandoned gravel quarry storage reservoirs are lower) and is the most distant point of all of the potential recapture alternative sites from the filtration plant or San Antonio Reservoir. Construction costs associated with new facilities will be offset by the savings resulting from decreased pumping requirements.

Figure 6 illustrates the possible disposition of recaptured flows under the operational modes described previously, assuming that the recapture facilities are located within the Sunol Valley between the filtration plant and the Hetch Hetchy Aqueduct (see Figure 2).

Under Recapture Mode A (see Figure 6a), the recaptured flows would be delivered to the filtration plant. The flows could not be pumped to San Antonio Reservoir, since under this mode of operation deliveries from the San Antonio Reservoir are being made to the filtration plant. For this mode of operation, the recapture facilities could deliver water directly to the filtration plant or to the suction side of the San Antonio Pumping Plant. Delivery to the filtration plant would require additional pumping capability relative to delivering to the San Antonio Pumping Plant, due to the additional required lift (see Figure 5). A short pipeline would be required to connect the recapture facilities to the existing pipeline in this case. Designing the facilities to deliver to the suction side of the San Antonio Pumping Plant results in a reduction in pumping requirement; however, an additional pipeline parallel to the existing 44-inch-diameter pipeline would be required to make that delivery.

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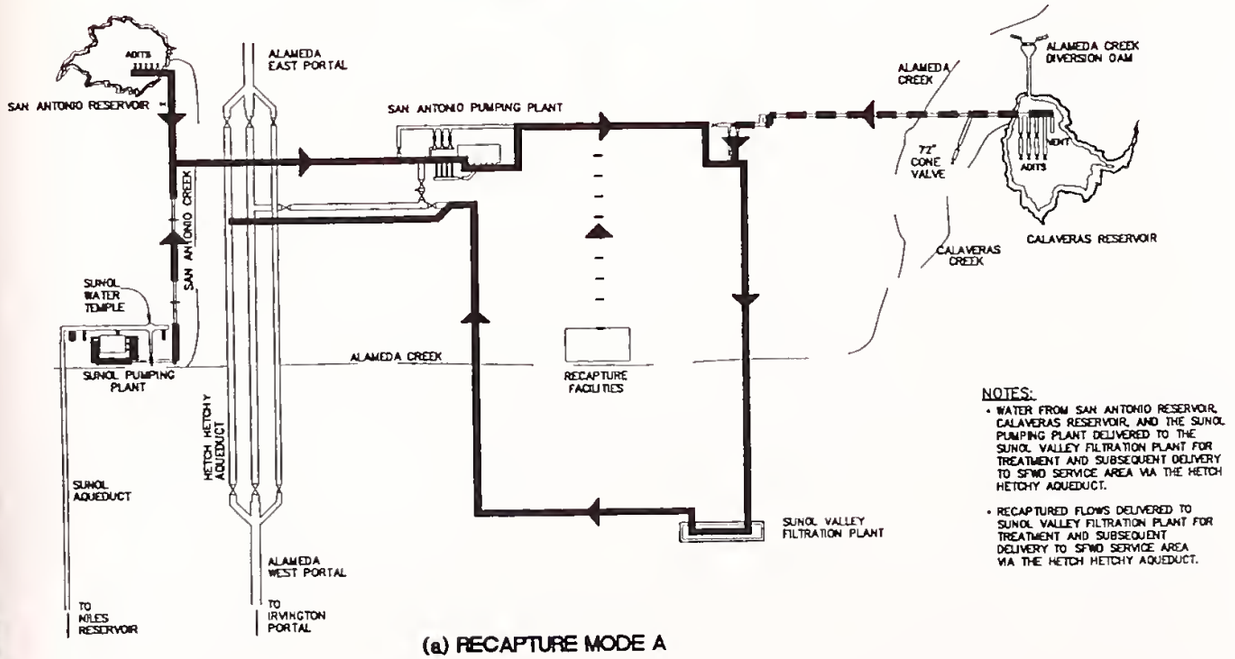
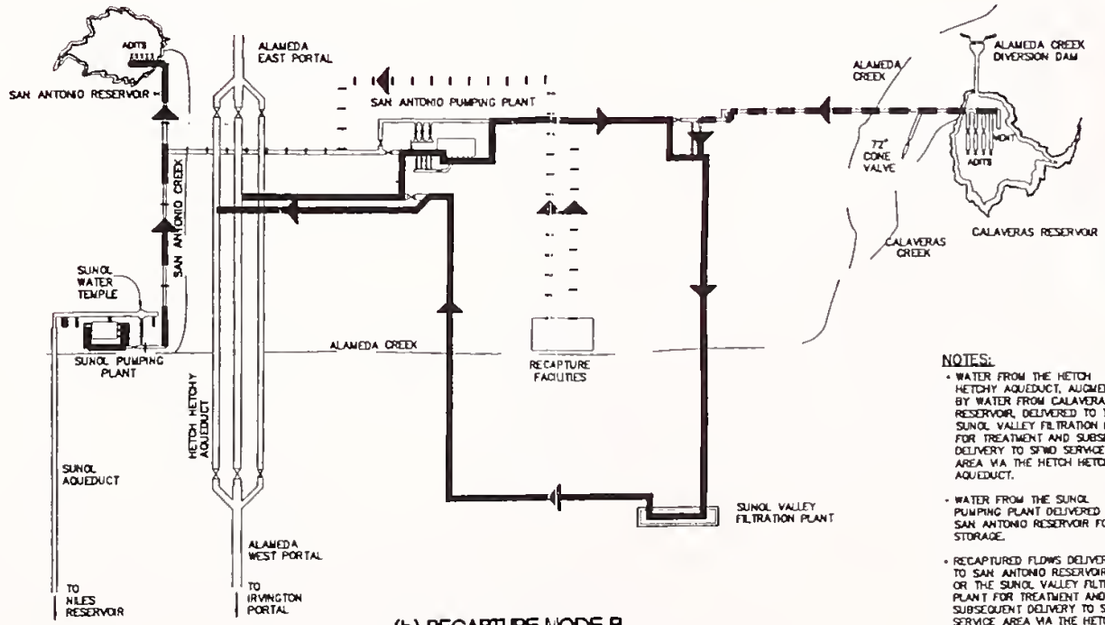


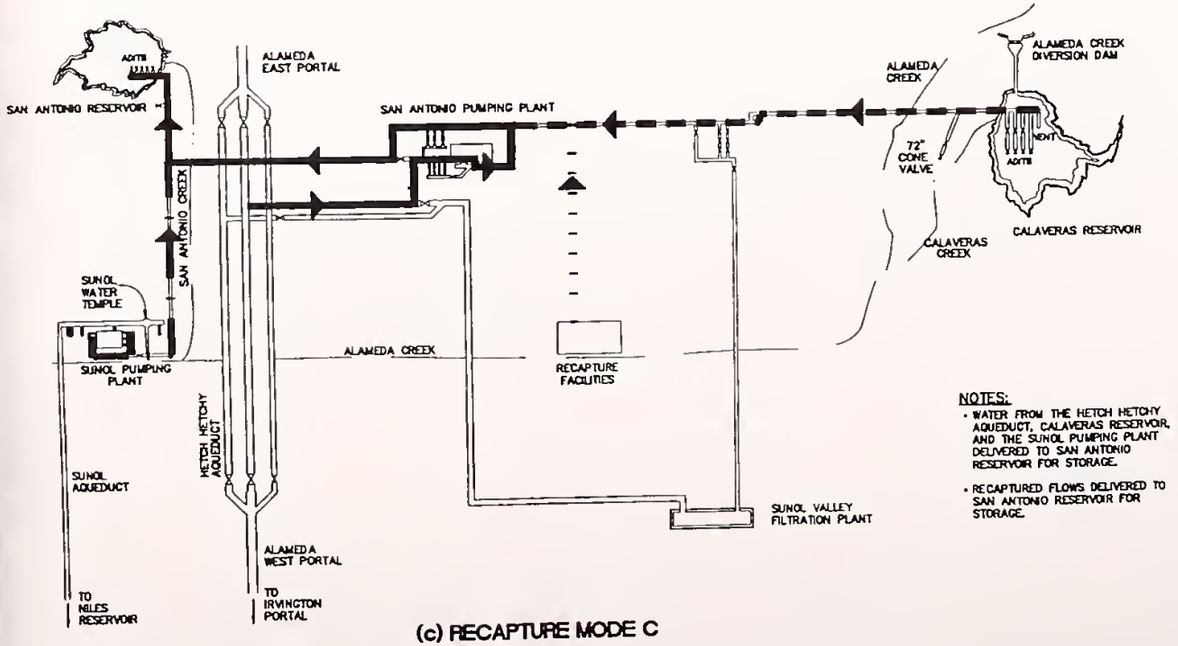
(a) RECAPTURE MODE A

NOTES:
- WATER FROM SAN ANTONIO RESERVOIR, CALAVERAS RESERVOIR, AND THE SUNOL PUMPING PLANT DELIVERED TO THE SUNOL VALLEY FILTRATION PLANT FOR TREATMENT AND SUBSEQUENT DELIVERY TO SFWD SERVICE AREA VIA THE HETCH HETCHY AQUEDUCT.
- RECAPTURED FLOWS DELIVERED TO SUNOL VALLEY FILTRATION PLANT FOR TREATMENT AND SUBSEQUENT DELIVERY TO SFWD SERVICE AREA VIA THE HETCH HETCHY AQUEDUCT.



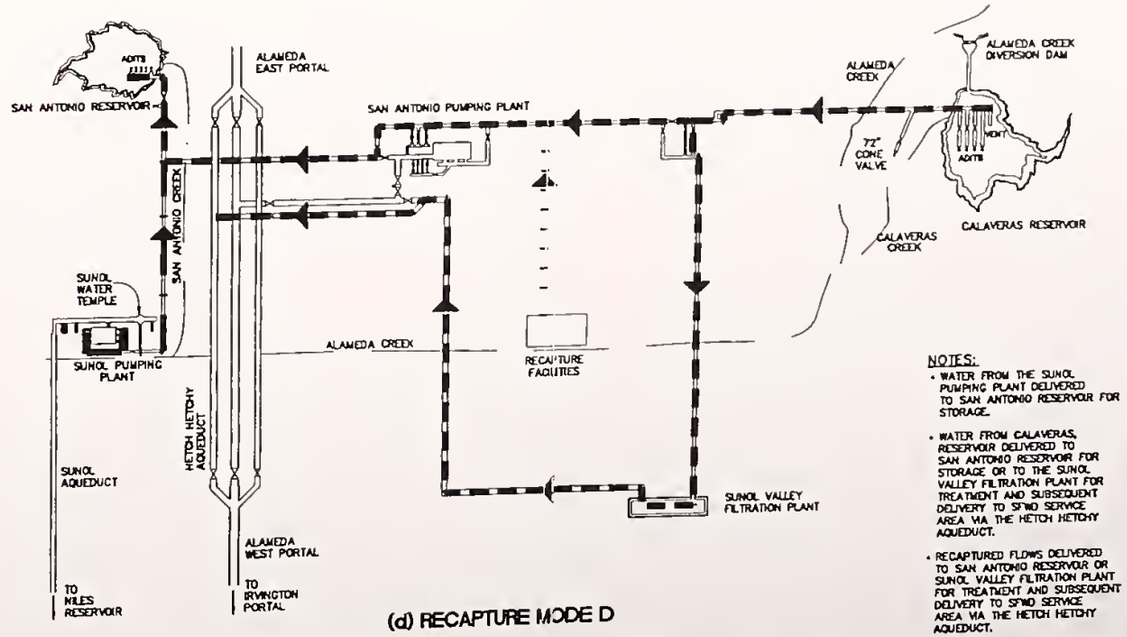
(b) RECAPTURE MODE B

NOTES:
- WATER FROM THE HETCH HETCHY AQUEDUCT, AUGMENTED BY WATER FROM CALAVERAS RESERVOIR, DELIVERED TO THE SUNOL VALLEY FILTRATION PLANT FOR TREATMENT AND SUBSEQUENT DELIVERY TO SFWD SERVICE AREA VIA THE HETCH HETCHY AQUEDUCT.
- WATER FROM THE SUNOL PUMPING PLANT DELIVERED TO SAN ANTONIO RESERVOIR FOR STORAGE.
- RECAPTURED FLOWS DELIVERED TO SAN ANTONIO RESERVOIR OR THE SUNOL VALLEY FILTRATION PLANT FOR TREATMENT AND SUBSEQUENT DELIVERY TO SFWD SERVICE AREA VIA THE HETCH HETCHY AQUEDUCT.



(c) RECAPTURE MODE C

NOTES:
- WATER FROM THE HETCH HETCHY AQUEDUCT, CALAVERAS RESERVOIR, AND THE SUNOL PUMPING PLANT DELIVERED TO SAN ANTONIO RESERVOIR FOR STORAGE.
- RECAPTURED FLOWS DELIVERED TO SAN ANTONIO RESERVOIR FOR STORAGE.



(d) RECAPTURE MODE D

NOTES:
- WATER FROM THE SUNOL PUMPING PLANT DELIVERED TO SAN ANTONIO RESERVOIR FOR STORAGE.
- WATER FROM CALAVERAS RESERVOIR DELIVERED TO SAN ANTONIO RESERVOIR FOR STORAGE OR TO THE SUNOL VALLEY FILTRATION PLANT FOR TREATMENT AND SUBSEQUENT DELIVERY TO SFWD SERVICE AREA VIA THE HETCH HETCHY AQUEDUCT.
- RECAPTURED FLOWS DELIVERED TO SAN ANTONIO RESERVOIR OR SUNOL VALLEY FILTRATION PLANT FOR TREATMENT AND SUBSEQUENT DELIVERY TO SFWD SERVICE AREA VIA THE HETCH HETCHY AQUEDUCT.

ALAMEDA CREEK WATER RESOURCES STUDY

OPERATIONAL MODES OF SUNOL VALLEY FACILITIES WITH FLOW RECAPTURE

SAN FRANCISCO WATER DEPARTMENT

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Under Recapture Mode B (see Figure 6b), the recaptured flows could be pumped to either the filtration plant or the San Antonio Reservoir. This mode of operation will occur principally in the spring during episodes of "yellow water" from the Hetch Hetchy system and coincides with the period of highest flow releases (20 cfs) recommended by BioSystems. Considerable flows to the filtration plant, in excess of demand, could result; thus, pumping the recaptured flows to the San Antonio Reservoir may be a preferred option. Delivering to the San Antonio Reservoir would require construction of a pipeline parallel to the existing 44-inch-diameter pipeline to a point north of the San Antonio Pumping Plant as well as sufficient pumping capacity to reach the San Antonio Reservoir. Deliveries to the filtration plant could be made as described under Recapture Mode A above (that is, directly to the filtration plant or by utilizing the San Antonio Pumping Plant as a booster plant).

Under Recapture Mode C (see Figure 6c), recaptured flows could be delivered to either San Antonio Reservoir or the filtration plant. This mode of operation typically occurs as a result of a decrease in demand within the SFWD service area. Thus, it is most likely that flows will be delivered to San Antonio Reservoir since there will be no need to immediately treat the water. This mode of operation would require a pipeline connecting the recapture facilities with the existing 44-inch-diameter pipeline and sufficient pumping capacity to reach the San Antonio Reservoir.

Under Recapture Mode D (see Figure 6d), recapture flows could be delivered to either San Antonio Reservoir or the filtration plant. If water from Calaveras Reservoir is being delivered to the filtration plant, recaptured flows could be delivered to either the filtration plant or San Antonio Reservoir. If water from Calaveras Reservoir is being delivered to San Antonio Reservoir, recaptured flows would also be delivered to San Antonio Reservoir. In either case, a pipeline is required to connect the recapture facilities to the existing 44-inch-diameter pipeline, as is sufficient pumping capability to reach either the filtration plant or San Antonio Reservoir.

The salient fact to note under all these operational modes is that, under the most likely operational scenarios, integration of the recapture facilities with the existing facilities will only **require** a single pipeline interconnection. An additional pipeline parallel to the existing line would offer greater flexibility during periods when Hetch Hetchy "yellow water" requires treatment, but is not required. Figure 7 illustrates the potential integration of the recapture facilities with the existing system.

Pumping recaptured flows to the filtration plant is the preferred option in most cases for several reasons. If the recaptured flows are pumped to the San Antonio Reservoir, at some point in the future, they must be pumped a second time to the filtration plant. Pumping the flows directly to the filtration plant at the time of recapture eliminates the need for pumping the same water twice. Additionally, the initial lift to the filtration plant is less than that required to deliver the flows to the San Antonio Reservoir (see Figure 5),

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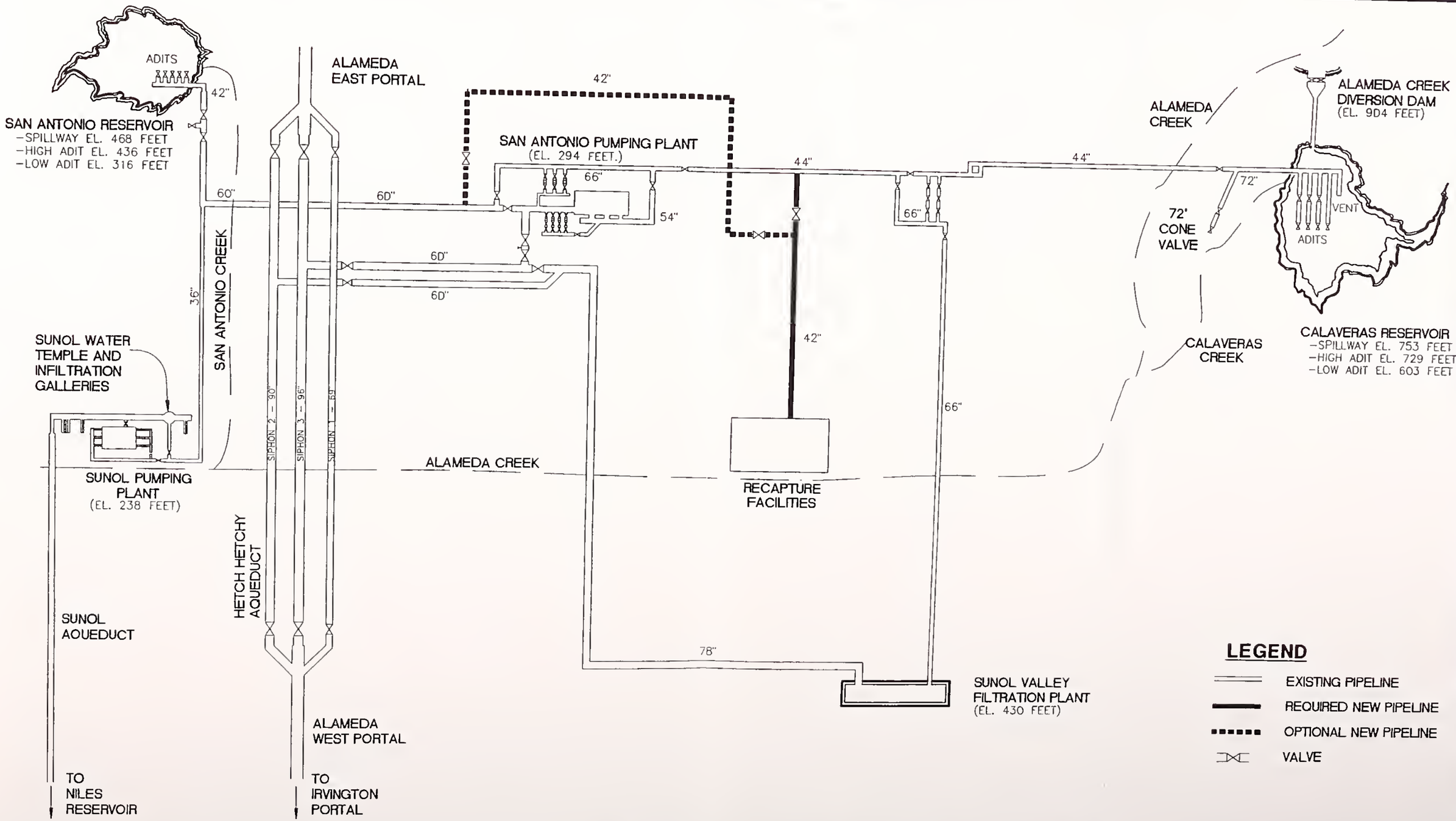

ALAMEDA CREEK WATER RESOURCES STUDY

SYSTEM DIAGRAM OF SUNOL VALLEY FACILITIES WITH RECAPTURE FACILITIES

SAN FRANCISCO WATER DEPARTMENT

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particularly after accounting for dynamic losses. By delivering the recaptured flows directly to the filtration plant, the SFWD can provide a year-round constant flow of water from a local supply.

EFFECTIVENESS OF THE FACILITIES

The primary objective of the flow recapture facilities is to recapture a sizeable volume of a valuable resource (a release of 20 cfs over a 24-hour period results in a total volume of water of nearly 13 million gallons) in an efficient and effective manner. Accomplishing this objective requires that the recapture facilities be located in such a way as to recover a high percentage of the released flows. Recovery of additional flows resulting from local runoff or spills at the Alameda Creek Diversion Dam is a secondary objective.

To maximize their effectiveness, the flow recapture facilities should address the potential for losses to subsurface seepage, evapotranspiration, and surface flow. Specific elements of the recapture facilities should address the prevention of each of these types of losses.

To be effective, the recapture facilities must prevent inflow of either surface water or groundwater to the existing gravel quarries. This can be accomplished by sealing the quarries from groundwater flow with subsurface cutoff walls, by locating the recapture facilities at the upper end of the Sunol Valley (near the filtration plant) where both surface and subsurface flows are confined, or by a combination of the two. Another advantage to locating the recapture facilities near the upper end of the Sunol Valley is that it mitigates the potential for losses due to surface flows down Niles Canyon.

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SECTION 3 FLOW RECAPTURE FACILITY ALTERNATIVES

B-E identified and evaluated four potential flow recapture facility alternatives:

- Recovery of surface flows utilizing an inflatable rubber dam to divert flows into abandoned gravel quarries in the Sunol Valley.
- Recovery of subsurface flows at the downstream end of the Sunol Valley utilizing a rehabilitated Sunol Infiltration Gallery.
- Recovery of subsurface flows on the floor of the Sunol Valley utilizing a subsurface cutoff wall in conjunction with either a dense, shallow well field or an infiltration gallery.
- Recovery of surface and subsurface flows near the filtration plant utilizing an inflatable rubber dam with a subsurface cutoff wall in conjunction with either a streamside intake structure or an infiltration gallery.

B-E identified the major elements required to construct each of these alternatives, selected appropriate locations for their effective implementation, and identified ancillary improvements to the existing facilities required to effectively implement the flow release program.. Operational procedures required to integrate the recapture facilities with the existing system were discussed in Section 2 of this report.

USE OF ABANDONED GRAVEL QUARRIES

SFWD leases lands in the lower portion of the Sunol Valley to two gravel quarry operators. Substantial quarry operations exist in the valley at this time and will continue into the near future. A moratorium on the expansion of quarry operations in the valley is in effect until completion of this study. The report *Groundwater and Aggregate Resources, Sunol Valley* by Luhdorff and Scalmanini Consulting Engineers (December 1993) provides a complete history of quarry operations in the valley and a description of existing plans for reclamation.

One potential flow recapture alternative identified by B-E entails reclamation of abandoned gravel quarries. Under this alternative, gravel quarries within the Sunol Valley developed on lands leased from the SFWD would be reclaimed as storage reservoirs as their mining capacity is exhausted. Reclaimed gravel quarries could serve as:

- **Regulatory Reservoirs** whereby abandoned quarries would function exclusively as regulating reservoirs with storage drawn down during dry years or during the late summer. No consideration would be given to recreational use.

- **Recreational Reservoirs** whereby abandoned quarries would be dedicated to recreational usage with no provision for lowering or drafting the reservoir.

- **Multiple Use (Recreational/Seasonal Storage) Reservoirs** whereby recreational usage would be combined with seasonal drawdown in the fall after cessation of peak recreation usage. Water supply benefits would occur because of the additional storage capability, but would be limited by restrictions on operations (i.e., withdrawals limited to the fall after cessation of peak recreational demands).

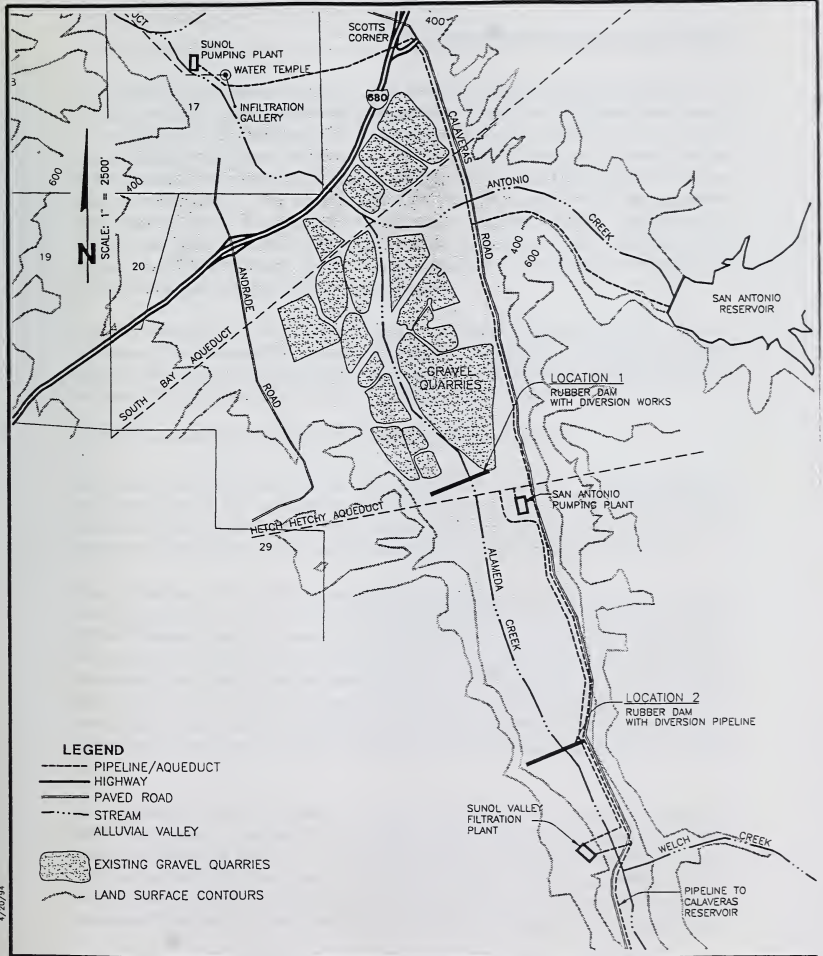
- **Multiple Use (Recreational/Emergency Storage) Reservoirs** whereby abandoned quarries would be operated primarily for recreation. Storage in the quarries would be considered as an emergency reserve for use during Hetch Hetchy Aqueduct outages or during extreme drought years when all other water supplies are depleted.

Use of the quarries as reservoirs for any of the above uses would require diversion works on Alameda Creek for directing flows into the abandoned quarries. Figure 8 illustrates two possible locations for such diversion works.

At Location 1, a diversion dam (possibly a reinforced concrete weir with an inflatable rubber dam section) spanning Alameda Creek downstream of the Hetch Hetchy Aqueduct would divert flows by gravity into the uppermost (southernmost) gravel quarry. The width of the Alameda Creek stream channel at this location is about 1,100 feet. Low level alluvium terraces border the channel on the east and west; the overall width of the valley floor at this location is about 2,300 feet.

Location 2 is located upstream where the Alameda Creek stream bed is more confined. At this location, the valley is about 1,200 feet in width. The stream channel is about 400 feet wide; thus, a much smaller diversion dam would be required. Diversion at this location would require a pipeline to deliver recaptured water to the uppermost quarry. This delivery could probably be made by gravity, but may require pumping.

Multiple quarries could be connected by pipelines or spillways operated by gravity. Alternatively, pumping facilities could be utilized to disperse water among the quarries. In addition to recaptured fishery flow releases, the quarries could be utilized to store overflows from Calaveras Reservoir, San Antonio Reservoir, or the Hetch Hetchy Aqueduct. Recovery of water from the quarries would require pumping facilities at one or more of



ALAMEDA CREEK WATER RESOURCES STUDY

RECAPTURE ALTERNATIVE
GRAVEL QUARRIES AS STORAGE RESERVOIRS

SAN FRANCISCO WATER DEPARTMENT

the quarries for extraction of water for delivery to the filtration plant for treatment. The pumping facilities should be provided with sufficient horsepower to deliver water directly to the filtration plant, although, under certain operational scenarios, the San Antonio Pumping Plant could conceivably be utilized as a booster plant for water extracted from the gravel quarries. The current leases limit quarry operations to a maximum depth of 140 feet below existing ground. The limit may, however, be extended to 200 feet below existing ground in the future. In either case, the water extraction pumping facilities must address the potential static lift required to remove water from the quarries. As illustrated on Figure 5, a static lift of nearly 300 feet could be required to deliver water from the lower depths of the gravel quarries to the filtration plant.

It may be decades before the total cessation of quarrying operations in the valley. Thus, the quarries will not be available for storage purposes in the near future. At best, incremental opportunities may exist for utilization. In the short term, the quarries cannot be relied upon for either the storage or recovery of fishery releases from Calaveras Reservoir.

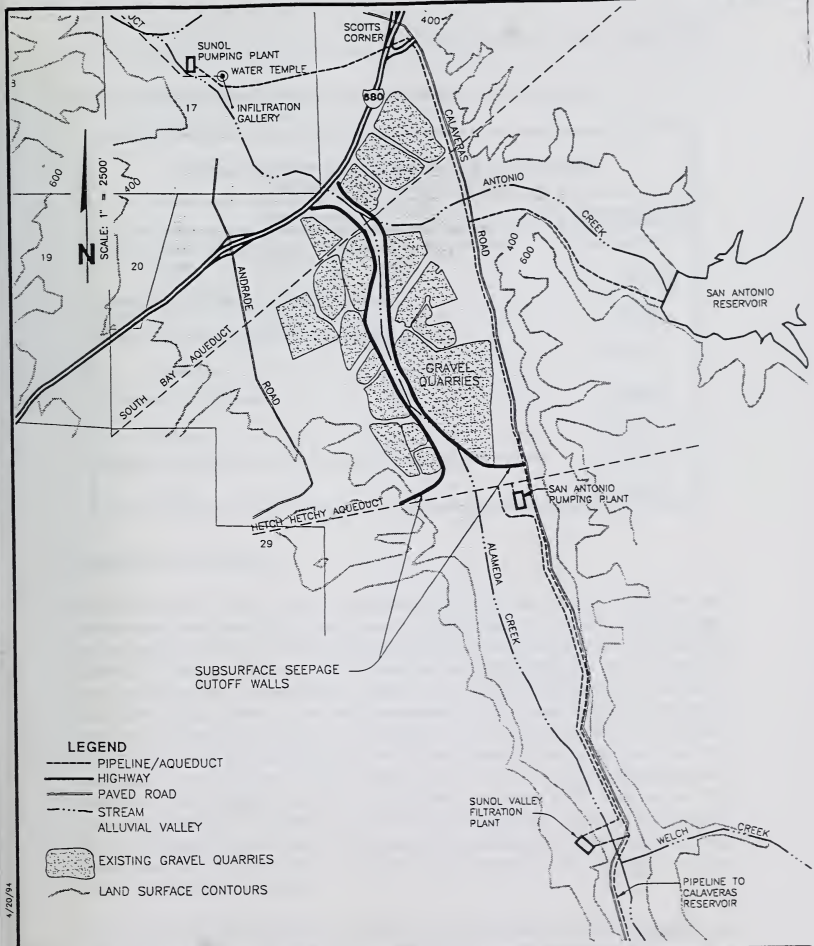
REHABILITATION OF THE SUNOL INFILTRATION GALLERY

The Sunol Infiltration Gallery could be rehabilitated to recapture the fish releases as subsurface flow at the downstream end of the Sunol Valley. Flows recaptured at the infiltration gallery would be pumped by the Sunol Pumping Plant to either the San Antonio Reservoir or the filtration plant under the operational modes described in Section 2.

The dewatering of the shallow surficial alluvial aquifer in the Sunol Valley by gravel quarrying operations upstream has significantly impacted the yield of the infiltration gallery. If the infiltration gallery is to serve as a viable recapture facility, extensive cutoff walls must be constructed through the Sunol Valley, as shown on Figure 9, to prevent infiltration into the existing (and potential future) gravel quarries. Over three miles of subsurface seepage cutoff walls would be required to prevent seepage into the existing gravel quarries. These cutoff walls would extend to depths between 50 and 100 feet to key into the relatively impermeable Livermore Formation underlying the surficial alluvium on the Sunol Valley floor.

The infiltration gallery is currently in a state of disrepair; thus utilization of the Sunol Infiltration Gallery to recapture the flow releases would require rehabilitation of the existing 2,000-foot infiltration gallery. A reconnaissance-level investigation suggests that about 1,000 feet of the infiltration gallery is salvageable, while the remaining 1,000 feet must be removed and replaced. The existing Sunol Pumping Plant would be utilized to pump the recaptured flows either to San Antonio Reservoir or to the filtration plant for treatment.

FIGURE 9



ALAMEDA CREEK WATER RESOURCES STUDY

RECAPTURE ALTERNATIVE
REHABILITATION OF SUNOL INFILTRATION GALLERY

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Table 2 presents an estimate of the costs of implementing this alternative.

Table 2
REHABILITATION OF SUNOL INFILTRATION GALLERY
ESTIMATE OF CAPITAL COSTS

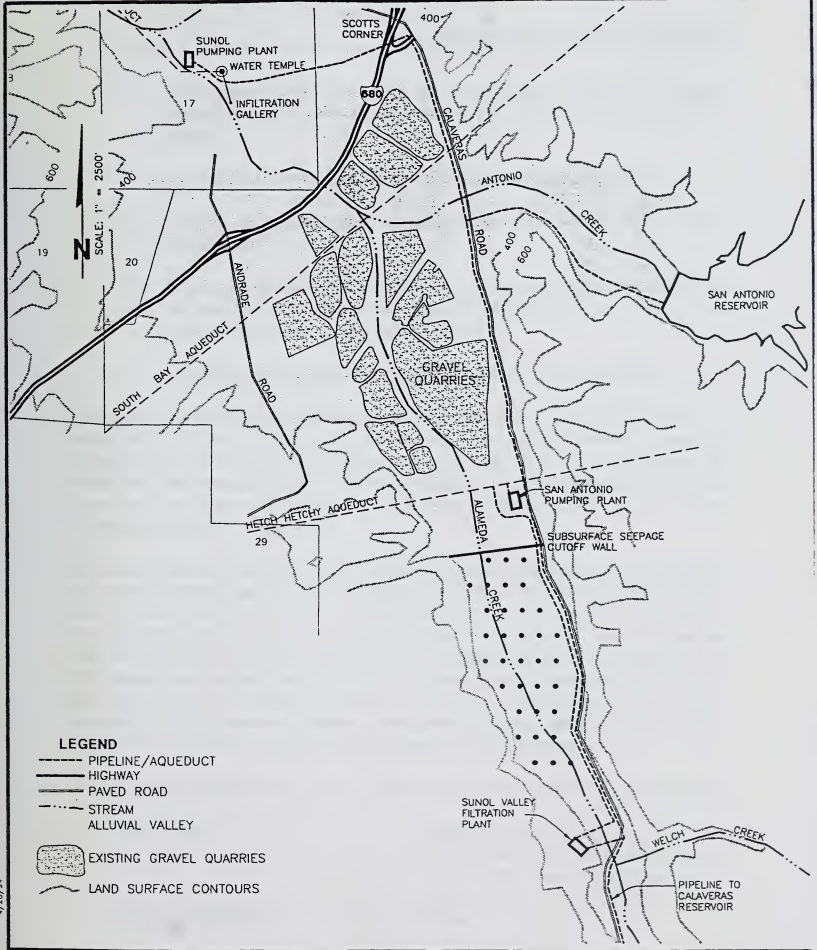
Item Description	Estimated Cost
Cutoff Wall–3.1 miles in length to an assumed average depth of 75 feet	$10,300,000
Rehabilitate 1,000 feet of infiltration gallery	300,000
Remove and replace 1,000 feet of infiltration gallery	550,000
Subtotal:	$11,150,000
Contingency at 25 percent	2,790,000
Subtotal:	$13,940,000
Engineering, administration, and construction support at 15 percent	2,090,000
Total:	$16,030,000

SUBSURFACE RECOVERY

Prior to this study, there was some expectation that conjunctive use of groundwater and surface water in the Sunol Valley could provide opportunities for recapture of flow releases. This expectation derived from the belief that the aquifer characteristics of the upper alluvial material, as well as the underlying Livermore gravel formation, were conducive to groundwater extraction development. Because of gravel mining operations in the valley, the shallow aquifer system is essentially nonexistent in the central portion of the Sunol Valley and is drained in most of the remainder of the central portion of the valley. Consequently, well field development would rely primarily on production from the underlying Livermore gravels. Aquifer tests conducted by Luhdorff and Scalmanini (see *Groundwater and Aggregate Resources, Sunol Valley*, December 1993) indicate that the Livermore formation is not suitable for groundwater development. Thus, the only available option with regard to groundwater development is the development of the shallow alluvial aquifer system in the upper end of the Sunol Valley between the filtration plant and the Hetch Hetchy Aqueduct crossing.

Figure 10 shows the potential general location of a dense, shallow well field. Integration of the well field with the existing facilities would require a number of additional elements:

FIGURE 10



ALAMEDA CREEK WATER RESOURCES STUDY

RECAPTURE ALTERNATIVE
DENSE, SHALLOW WELL FIELD

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- A subsurface cutoff wall above the Hetch Hetchy Aqueduct to mitigate groundwater flow to the lower portion of the valley into the existing gravel quarries.

- A system of shallow wells completed in the upper alluvial material.

- A header system connecting the discharge lines of the shallow wells to a central pumping plant.

- A pumping plant with sufficient capacity and horsepower to deliver the recaptured flow with head sufficient to meet the hydraulic requirements of the existing facilities under any operational mode.

- A pipeline to connect the pumping plant with the existing facilities.

The intent of the shallow well field is to recapture flow after it has fully infiltrated the stream bed of Alameda Creek. As experimentally observed by BioSystems during its investigation, releases from Calaveras Reservoir of up to 30 cfs did not fully infiltrate the stream bed until reaching the Hetch Hetchy Aqueduct. Thus, the subsurface cutoff wall should be located down the valley to permit development of as much of the shallow alluvium as possible (see Figure 10).

At the location shown on Figure 10, the cutoff wall would fully extend across the valley floor from Calaveras Road on the east to competent bedrock (Panoche Formation) on the west, a distance of about 2,200 feet. The Alameda Creek stream channel at this point is about 1,100 feet wide with low level alluvium terraces to the east and west of the stream, each about 500 feet wide. The alluvium through this portion of the valley is about 50 feet in thickness; thus, the cutoff wall should be completed to depths between 50 to 55 feet to key the wall into the underlying Livermore formation. Even then, despite the low permeability of the Livermore formation, some groundwater flow would occur beneath the cutoff wall. The volume of this underflow, however, should be small.

A typical shallow well for the recapture facilities would have the following characteristics:

- Well depth: 50 feet to base of alluvium; 5 to 10 feet additional depth to form a "sump" in the Livermore Formation

- Depth to static water: 20 feet

- Saturated thickness of alluvium: 30 feet

- Well screen interval: 25 feet, from 30 to 55 feet below the surface

Although pumped well test data were not available, and wells were not available for testing as part of this study, the potential yields of wells completed in the shallow alluvium near the treatment plant were estimated. Based on the hydraulic conductivity values provided by Luhdorff and Scalmanini (see *Groundwater Aggregate Resources, Sunol Valley*, December 1993), the transmissivity of the alluvium could range between 15,000 and 45,000 gallons per day (gpd) per foot of alluvium. Utilizing these values for transmissivity and assuming wells constructed with the characteristics listed previously, potential well yields could range between 150 and 450 gpm per well.

Even if the upper range of potential well capacity is achievable, a recapture well network of 20 to 50 wells would be required to recapture the expected 20 to 50 cfs of available flows (50 cfs equals 22,440 gpm). Preliminary analysis indicates that this arrangement is not practical. Calculations indicate that there is insufficient area available to prevent interference between adjacent wells, resulting in unacceptable drawdown conditions. In those cases where acceptable drawdown was calculated, an unacceptable number of wells was required to deliver the flow.

Additionally, because of the width of the Alameda Creek stream bed in this area, many of the wells would have to be placed within the Alameda Creek floodway, making them highly susceptible to inundation and damage. Insufficient overbank exists to allow for all wells to be placed out of the floodway.

Further confirmation of shallow well yields and aquifer characteristics would need to be undertaken to refine consideration of wells for potential recapture of live stream releases after infiltration. Such confirmation, which should include well construction and testing, would also allow consideration of well spacing to effect recapture via a local regional pumping depression without adverse mutual pumping interference that would impact pump capacity and performance in individual wells.

As an alternative to the well field, subsurface flows could be recovered utilizing an infiltration gallery near the Hetch Hetchy Aqueduct. The infiltration gallery would drain into the sump of a multibay pumping plant (potential characteristics of such a pumping plant are described in the next section). This would require a subsurface cutoff wall, a 2,000-foot infiltration gallery, a pipeline to a sump and pumping plant, and a pipeline connection to the existing system.

Table 3 presents an estimate of the costs of constructing a subsurface cutoff wall and flow recapture with an infiltration gallery. implementing this alternative.

Table 3
SUBSURFACE RECAPTURE WITH CUTOFF WALL AND INFILTRATION GALLERY
ESTIMATE OF CAPITAL COSTS

Item Description	Estimated Cost
Cutoff Wall–2,200 feet to a depth of 100 feet	$3,960,000
Infiltration gallery–2,000 feet	850,000
Pumping plant with reinforced concrete sump (2,400 hp)	1,800,000
Pipeline–1,000 feet of 42-inch-diameter RCP with appurtenances	160,000
Subtotal:	$6,770,000
Contingency at 25 percent	1,690,000
Subtotal:	$8,460,000
Engineering, administration, and construction support at 15 percent	1,270,000
Total:	$9,730,000

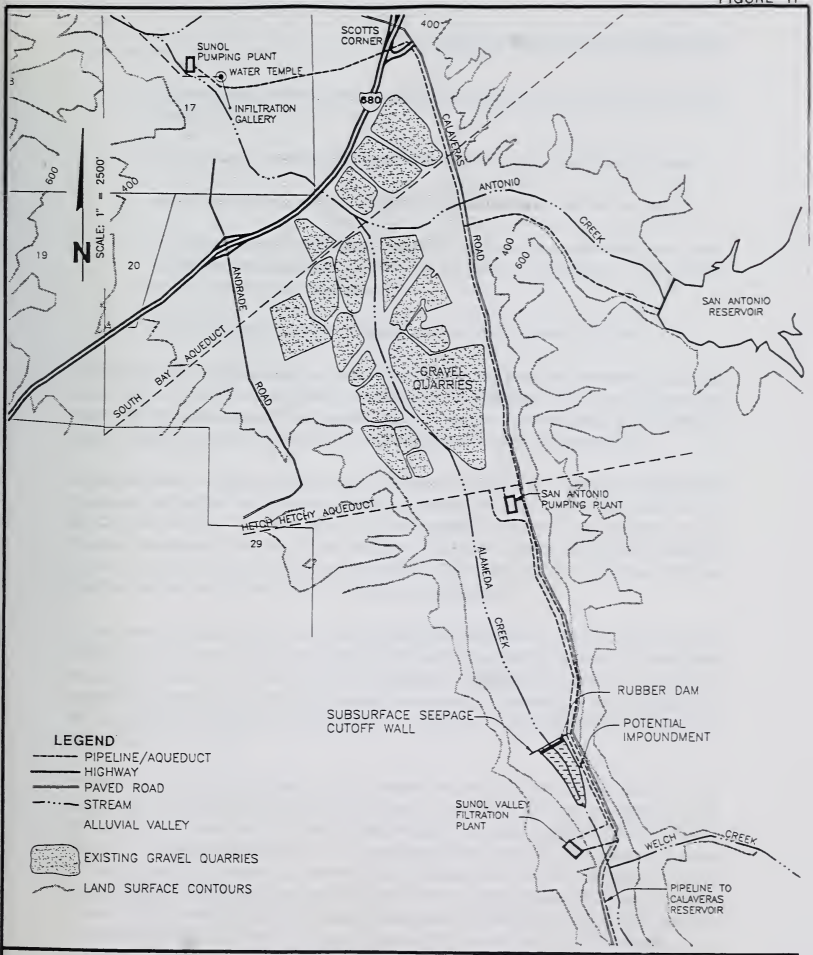
SURFACE IMPOUNDMENT

Relying solely on subsurface recapture of the fishery flow releases would have one serious drawback: specifically, surface flows that did not fully infiltrate Alameda Creek streambed upstream of the subsurface cutoff wall and infiltration gallery would not be recaptured. An alternative to subsurface flow recapture is surface impoundment.

Surface impoundment permits locating the recapture facilities farther up the valley, closer to the filtration plant, as shown on Figure 11 (the subsurface cutoff wall for subsurface recapture was located near the Hetch Hetchy Aqueduct due to the fact that the experimental releases observed by BioSystems did not fully infiltrate the Alameda Creek stream bed until just before they reached the Hetch Hetchy Aqueduct). Two principal advantages result: the recapture facilities are in closer proximity to the filtration plant, which diminishes the pumping requirements (and costs); and, because the valley is much narrower, the flows are constrained, which improves the potential effectiveness and efficiency of the recapture facilities.

Figure 11 shows the general location, about 1,500 feet downstream of the filtration plant, of a potential surface impoundment site. This location is close to the filtration plant, has sufficient area upstream for impoundment purposes, and has sufficient overbank for locating pumping facilities. Integration of the surface impoundment facilities with the existing facilities would require a number of additional elements:

FIGURE 11



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ALAMEDA CREEK WATER RESOURCES STUDY

RECAPTURE ALTERNATIVE
RUBBER DAM WITH SURFACE IMPOUNDMENT

SAN FRANCISCO WATER DEPARTMENT

APRIL 1994

- A gravity dam, or weir, with a rubber dam section to impound surface flows in Alameda Creek.
- A subsurface cutoff wall at or near the dam to prevent subsurface seepage.
- An intake structure, either a streamside structure or an infiltration gallery.
- A pumping plant with sufficient capacity and horsepower to deliver recaptured flows with head sufficient to meet the hydraulic requirements of the existing facilities under any operational mode.
- A pipeline to connect the pumping plant with the existing facilities.

This location for the rubber dam was identified because the extensive overbank on the east side of Alameda Creek at that location is suitable for construction of the required pumping plant. The overbank affords the pumping plant protection against high flows in Alameda Creek. It also provides easy access to the pumping plant from Calaveras Road.

At this location, the valley floor is about 1,200 feet in width. The Alameda Creek stream channel is well-defined and is about 400 feet in width. The east overbank is underlain by an alluvium terrace. No subsurface data are available; however, the thickness of this alluvium is estimated between 50 and 100 feet. The stream channel is probably underlain by less than 50 feet of gravel, sand, and alluvium. The valley is bordered by the Calaveras Fault on the east and by the Panoche Formation on the west.

A cutoff wall at this location would extend from Calaveras Road on the east to the Panoche Formation on the west, a distance of about 1,000 feet. The cutoff wall should be completed to a depth sufficient to key into relatively impermeable material (the Livermore Formation) beneath the stream bed. Test borings would be required to evaluate the actual thickness of the alluvium on the depth to groundwater. The cutoff wall will minimize subsurface seepage under the dam.

The dam should span the Alameda Creek stream bed at this location. The majority of the dam could be constructed of reinforced concrete. A portion of the dam, probably between 100 and 250 feet, would be an inflatable rubber dam. The dam would be about five feet in height and would be designed to act as a broad-crested weir at high flows. A dam of about five feet in height is required to ensure proper submergence for efficient operation of the pumping plant. The rubber dam portion of the dam would be deflated to allow high flows to pass without overtopping the facilities. Sluice gates will also be provided in the concrete portions of the dam. A five-foot dam at this location would inundate about seven acres, impounding about 30 acre-feet of water.

The pumping plant would be provided with a battery of pumps. A potential arrangement would be to provide four pumps with capacities of 5, 10, 20, and 30 cfs, respectively. Such an arrangement could efficiently delivery flowrates over the entire anticipated 0 to 50 cfs operating range of the recapture facilities. Each pump would have sufficient capability to deliver water to either the filtration plant or the San Antonio Reservoir under any mode of operation. Variable speed motors could be effective in this situation to reduce energy costs. An additional pump bay would be provided to provide for the contingency of the future need for additional capacity or in the case of repairs to an existing pump or wet well.

Flows would be recaptured and diverted to the pumping plant sump utilizing either a streamside intake structure situated at the bank of Alameda Creek adjacent to the forebay created by the rubber dam, or a bed-mounted infiltration gallery underlying the forebay. The disadvantage of the streamside intake structure is that only surface flows would be recapturable (at low flows, we could expect that the flow releases will have fully infiltrated the Alameda Creek streambed prior to reaching this location). A subsurface infiltration gallery could, however, capture both subsurface and surface flows (surface flows would be impounded directly over the infiltration gallery). The relative effectiveness of each alternative subject to the sedimentation that would occur in the forebay should also be investigated further. The disadvantage of an infiltration gallery is that sedimentation in the forebay could degrade vertical permeability to such an extent that insufficient volumes of flow would be recaptured.

Table 4 presents an estimate of the costs of recapturing flows near the filtration plant utilizing a rubber dam to impound water over a bed-mounted infiltration gallery.

Table 4
SUBSURFACE RECAPTURE WITH RUBBER DAM AND INTAKE
ESTIMATE OF CAPITAL COSTS

Item Description	Estimated Cost
Cutoff Wall–1,000 feet to a depth of 50 feet	$ 330,000
Concrete weir–450 feet wide with 200-foot rubber dam	2,000,000
Infiltration gallery–2,000 feet	420,000
Pumping plant with reinforced concrete sump (2,400 hp)	1,800,000
Pipeline–500 feet of 42-inch-diameter RCP with appurtenances	80,000
Subtotal:	$4,630,000
Contingency at 25 percent	1,160,000
Subtotal:	$5,790,000
Engineering, administration, and construction support at 15 percent	870,000
Total:	$6,660,000

ANCILLARY FACILITIES

During the fishery feasibility evaluation, the existing 72-inch cone valve at the base of Calaveras Dam was utilized to make experimental flow release for observation by BioSystems. The cone valve currently discharges onto the apron of the Calaveras Dam spillway. At a discharge flow rate of 30 cfs, the jet of water from the cone valve impinged upon the banks of Calaveras Creek downstream of the end of the spillway apron resulting in significant erosion of the streambed channel invert and bank. To prevent such erosion from occurring, the channel should be improved in this area prior to commencement of the flow release program. Armoring of the channel in this area to prevent erosion would require placement of riprap. No other channel improvements are required.

During the experimental release program, there was no evidence downstream that the flow releases will result in any undue damage to the stream channel through the Sunol Valley. Flow through the Sunol Valley Regional Park caused no damage to recreational facilities. The Sunol Valley Filtration Plant Bridge showed no adverse effects. At this time, channel improvements are not required.

Utilization of the 72-inch cone valve for the flow release program may not be appropriate. The cone valve was not designed for year-round operation at the flow rates and operating heads required to support the fishery (see Table 1 in Section 2). Operating the cone valve in this manner could result in degradation of the valve over time. Similarly, use of the butterfly isolator valve on the 72-inch pipeline feeding the cone valve is not advisable (see Figure 3).

An alternative to utilizing the cone valve or the butterfly valve would be to tap the existing 72-inch pipeline with an 18-inch-diameter flanged outlet. A sleeve valve could then be utilized for delivering the flow releases to the Calaveras Creek streambed. Sleeve valves are specifically designed for situations such as this, where excess head must be dissipated. Table 5 presents an estimate of the capital costs of a sleeve valve installation. An ultrasonic flowmeter installation for accurately measuring the flow releases is included in the estimate.

Table 5
FLOW RELEASE VALVE AT CALAVERAS RESERVOIR
ESTIMATE OF CAPITAL COSTS

Item Description	Estimated Cost
18-inch flanged outlet	$ 3,000
18-inch butterfly valve with electric actuator	7,500
18-inch sleeve valve with electric actuator	100,000
18-inch-diameter steel pipe, ¼ wall, 50 feet	6,000
Air release valve	4,000
Flowmeter	30,000
Pipe support with footing(s)	12,500
Concrete support slab	5,000
Thrust block	5,000
Subtotal:	$173,000
Contingency at 25 percent	43,000
Subtotal:	$216,000
Engineering, administration, and construction support at 15 percent	32,000
Total:	$248,000

Finally, an alternative to either utilizing the existing 72-inch valves (cone valve or butterfly valve) or installing a sleeve valve would be to install a sacrificial butterfly valve on the 18-inch-diameter. In this instance, the butterfly valve would be utilized to deliver the flow releases under operating conditions deleterious to the valve. The valve would require replacement from time to time; however, the cost of replacement (including labor) would be about $15,000. The frequency with which the valve would be replaced would be dependent upon the conditions under which it was operated.

SECTION 4 SUMMARY AND RECOMMENDATIONS

SUMMARY

The SFWD retained B-E to identify and evaluate alternatives for improving water resources operations in the Alameda Creek Watershed. Included in that evaluation was an examination of the feasibility of establishing a trout fishery in portions of Calaveras Creek and Alameda Creek below Calaveras Reservoir utilizing releases from Calaveras Reservoir.

BioSystems, under subcontract to B-E, determined that establishment of a trout fishery is feasible and in their report *Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan* (February 1993) made recommendations on the timing and volume of water released from Calaveras Reservoir required to support such a fishery. Likewise, Ogden concluded in their report *Alameda Creek Revegetation/Restoration Report* (May 1993) that riparian conditions on Calaveras Creek and Alameda Creek are conducive to establishment of a trout fishery. An operations model of the Alameda Creek Watershed developed by B-E (see *Alameda Creek Watershed Study, Report on Watershed Operations*, Bookman-Edmonston Engineering, Inc., January 1994) confirmed the availability of requisite flows for support of such a fishery.

Given that establishment of a trout fishery is feasible, B-E identified alternatives for recapturing the flows released from the Calaveras Reservoir to support the fishery for return to SFWD's water transmission system. B-E identified and evaluated four principal alternatives for the recapture of the fishery releases:

- Diversion of the flows into abandoned gravel quarries for storage.
- Subsurface recapture of the flows at the existing Sunol Infiltration Gallery.
- Subsurface recapture of the flows utilizing a shallow, dense well field or a new infiltration gallery constructed near the Hetch Hetchy Aqueduct.
- Surface recapture of the flows near the filtration plant utilizing a rubber dam for surface impoundment.

Abandoned gravel quarries could potentially be used for storage as storage reservoirs. The quarries could be operated as:

- Regulating reservoirs.
- Multiple-use reservoirs for any combination of recreation, seasonal storage, or emergency storage.

Pumping facilities would be required to extract water from the gravel quarries for reintroduction to the SFWD's system. In the long term, use of the gravel quarries for these purposes is feasible. In the short term, however, ongoing gravel extraction operations make use of the quarries as reservoirs impractical. Conversion of abandoned quarries for use as reservoirs in the future will depend on the rate at which quarrying activity proceeds.

Use of the Sunol Infiltration Gallery to recapture the fishery releases will require extensive rehabilitation of the infiltration gallery, as well as construction of over three miles of subsurface cutoff walls to prevent seepage of groundwater into the existing gravel pits. This alternative is possible, but would require excessive capital costs (relative to other available alternatives). Additionally, the infiltration gallery is the lowest point in the Sunol Valley facilities and, therefore, the greatest energy costs are associated with this alternative.

Prior to this study, there was a belief that conjunctive operations could be practiced in the Sunol Valley and that recapture of the fishery flow releases could be made part of those operations. An evaluation of the hydrogeological conditions in the Sunol Valley by Luhdorff and Scalmanini (see *Groundwater and Aggregate Resources, Sunol Valley*, December 1993) revealed that conjunctive operations in the Sunol Valley were not feasible for a number of reasons, including:

- The low hydraulic conductivity of the underlying Livermore Formation throughout the valley floor.

- The impact of the gravel quarry operations on the transmissivity of the thin surficial alluvial aquifer overlying the Livermore Formation.

Although conjunctive operations are not feasible in the Sunol Valley, the recapture of fishery flow releases utilizing subsurface collection facilities is possible. B-E evaluated the recapture of the flow releases utilizing a cutoff wall to prevent seepage into the gravel quarries and a dense, shallow well field for recovery. The thin alluvial aquifer and the configuration of the Alameda Creek streambed on the valley floor make the operation of a dense, shallow well field impractical. Recapture of the subsurface flows utilizing an infiltration gallery upstream of a subsurface cutoff wall is a practical alternative, however.

Recapture of subsurface flows is a practical alternative under most conditions; however, high flows in Alameda Creek would not infiltrate the streambed and could be lost. Therefore, B-E evaluated the construction of a rubber dam for surface impoundment to capture these flows, in conjunction with a cutoff wall for capturing subsurface flows. A streamside surface intake structure was evaluated, as was a subsurface infiltration gallery. The infiltration gallery offers the greatest flexibility.

RECOMMENDATIONS

Based on our evaluation, B-E recommends that the SFWD recapture fishery flow releases utilizing surface impoundment over infiltration galleries. The infiltration galleries, in combination with a subsurface cutoff wall, will recapture subsurface flow as well. This solution offers the SFWD the greatest flexibility of any of the alternatives. Additionally, it requires the least pumping, minimizing energy requirements.

To provide the greatest flexibility, B-E recommends that the recapture facilities be provided with sufficient capability to pump a maximum flow of 50 cfs to either the San Antonio Reservoir or the filtration plant. The San Antonio Pumping Plant should not be relied on to relift the recaptured flows.

APPENDIX I

LETTER FROM THE STATE OF CALIFORNIA DEPARTMENT OF FISH AND GAME RECOMMENDING IMPLEMENTATION OF ALTERNATIVE 4 (PROTECTION AND ENHANCEMENT OF NATIVE RAINBOW TROUT AND NON-GAME FISHES) AS IDENTIFIED IN THE ALAMEDA CREEK WATERSHED STUDY, FISHERY RESTORATION FEASIBILITY EVALUATION AND PRELIMINARY RESTORATION PLAN, NOVEMBER 1993 (APPENDIX E)

E OF CALIFORNIA - THE RESOURCES AGENCY
PETE WILSON, Governor
EPARTMENT OF FISH AND GAME
ST OFFICE BOX 47
NTVILLE, CALIFORNIA 94599
) 544-5500

October 19, 1994

RECEIVED
OCT 24 1994
SFWD WATERSHED

Mr. Ed Stewart
Watershed Manager
San Francisco Water Department
Post Office Box 730
Millbrae, California 94030

Dear Mr. Stewart:

I am sorry about the delay in responding to the Water District's proposal concerning flows in Calavaras and Alameda creeks. In an effort to increase the biodiversity of aquatic life in Calavaras and Alameda creeks from Calavaras Dam to the Sunol filter plant, the Department of Fish and Game recommends restoration efforts be implemented that protect and enhance the native rainbow trout and non-game fishes. This is listed as Alternative 4 in the Alameda Creek Watershed Study Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan.

The Department has some concerns that should be considered in implementing this restoration plan. First, the plan describes water temperature as the limiting factor in the enhancement of native non-game fishes in Alameda Creek. The plan recommends a reduction of stream flow in an effort to increase water temperature suitable for non-game fishes. This reduction in stream flow also decreases the available habitat for both the native rainbow trout and native non-game fishes creating sub-optimal conditions for both groups. Second, the reduction in stream flow could have a negative affect on water quality which would inhibit production of warm and coldwater fishes.

The Department recommends that baseline data be collected on the fish species composition and abundance prior to the project and that a monitoring program be implemented for several years after project completion to evaluate the success of the project. Both native rainbow trout and native non-game fish populations should show a significant increase to consider the project a success. If stream flows specified by Alternative 4 fail to produce conditions that enhance both populations of fishes, the Department recommends revisiting the issue to discuss alternative flow options. The next likely action the Department would pursue would be the maximization of the native rainbow trout population from Calavaras Dam to the Sunol filter plant. This is described in Alternative 2 of the Alameda Creek Watershed Study Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan.

We appreciate your efforts and those of other San Francisco Water Department personnel in working closely with the Department to re-establish fish and wildlife habitat once lost to water development. We look forward to continuing a cooperative effort in implementing this project.

The Department coordinator for implementation of this project will be Kyle Murphy, Fishery Biologist. He can be reached at the Department of Fish and Game, 20 Lower Ragsdale Drive, Suite 100, Monterey, California 93940; telephone (408) 649-2883.

Sincerely,

Ken Aasen
for
Brian Hunter
Regional Manager
Region 3